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Pechan (E.H.) and Associates, Inc.
Springfield, VA

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ASSESSMENT OF NATIONAL AND REGIONAL ACID DEPOSITION PRECURSOR EMISSION TRENDS

by

James H. Wilson, Jr., Edward H. Pechan, Kristin Graves
E.H. Pechan & Associates, Inc.
Springfield, Virginia 22151

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EPA Project Officer

J. David Mobley
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT The report gives results of an analysis of national and regional acid deposition precursor emission trends, involving SOx, NOx, and VOCs. While the focus is on emissions during 1980-1985, comparisons are made (for perspective) with emission trends for 1940-1980. Study methods integrated data from the U.S. EPA's national emission trends reports, state and regional activity indicators, and plant level data for electric utilities and copper smelters. For 1980-1985, all three pollutants showed both annual declines and increases. The most pronounced decline was for SOx, with a net decrease of almost 11% from 1980 to 1985, most of which occurred between 1980 and 1982. National VOC emissions declined 7% from 1980 to 1985, but the change in NOx emissions was insignificant compared with potential uncertainties in the analysis methods. For a longer term, emission trends can be divided into three periods: (1) 1940 to the mid-1970s, when emissions increased in proportion to fuel use and the GNP; (2) the late 1970s to the early 1980s, the "emissions control era," when Clean Air Act programs produced a downward trend for all pollutants except NOx as the economy continued growing; and (3) since 1980, when relationships between emissions and the economy, fuel use, and regulations are making it more difficult to predict emissions in future years.

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Assessments	Sulfur Oxides	Stationary Sources	14B
Emission	Organic Compounds	Acid Rain	14G
Precipitation (Meteorology)	Volatility	Volatile Organic Compounds	20M
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ABSTRACT

An analysis was made of national and regional acid deposition precursor emission trends. Pollutants studied were sulfur oxides (SO_x), nitrogen oxides (NO_x), and volatile organic compounds (VOCs). While the focus is on emissions during 1980 through 1985, comparisons are made with emission trends from 1940 to 1980 for perspective. Study methods integrated data from the United States Environmental Protection Agency's (EPA's) national emission Trends reports, state and regional activity indicators, and plant level data for electric utilities and copper smelters. From 1980 to 1985, all three pollutants showed both annual declines and increases. The most pronounced decline was for SO_x, with a net decrease of almost 11 percent comparing 1980 and 1985 emission levels, most of which occurred between 1980 and 1982. National VOC emissions declined 7 percent between 1980 and 1985, while the change in NO_x emissions was insignificant compared with potential uncertainties in the analysis methods.

On a longer term perspective, emission trends can be divided into three periods. The 1940 to mid-1970s period was one of growing emissions when emissions increased in proportion to fuel use and Gross National Product (GNP). This was followed in the late 1970s and early 1980s by the "emissions control era" when programs enacted under the Clean Air Act produced a downward emission trend for all pollutants except NO_x while the economy was still growing. Most recently (since 1980), the relationships between emissions and the economy, fuel use, and regulations have become more complex. As a result, it is more difficult to predict how the combinations of economic growth and implementation of current control regulations will affect emissions in future years.

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EXECUTIVE SUMMARY

An analysis was made of national and regional acid deposition precursor emission trends. Pollutants studied were sulfur oxides (SO_x), nitrogen oxides (NO_x), and volatile organic compounds (VOCs). While the focus is on emissions during 1980 through 1985, comparisons are made with emission trends from 1940 to 1980 for perspective. Study methods integrated data from the United States Environmental Protection Agency's (EPA's) national emission trends reports, state and regional activity indicators, and plant level data for electric utilities and copper smelters.

U.S. EMISSION TRENDS FROM 1940 TO 1985

New Information Since 1983

Historical and current emission trends can be reasonably well represented by three time segments, as shown in Figure 43. Most recently, the relationships between emissions and the economy, fuel use and pollution control regulations have become more complex--in contrast to the emission trends evidenced before the early 1980s.

Significance of New Information

It is now extremely difficult to analyze how economic growth, fuel use, and pollution control regulations have affected and will affect man-made emissions. The difficulty of predicting emission trends for the next five or more years has created controversy among those interested in and affected by environmental regulations about whether emissions will increase or decrease during this period. Similarly, this difficulty has fostered controversy about the effect of existing environmental regulations on these emissions and whether additional or fewer regulations are needed.

Explanation for Change

Emission trends since 1940 break down into three periods. The 1940 to mid-1970s period (Figure 43) was one of emissions growth in which, generally, emissions increased proportionately with fuel use and GNP. The latter half of the 1970s and the early 1980s was the "emissions control era" in which programs enacted under the Clean Air Act produced a downward emission trend for all pollutants, except NO_x, while the economy and fuel consumption continued to grow. As shown in Figure 44 (discussed below), the relationships between emissions, the economy, fuel use, and regulations became more complex after 1983.

The main reason for this added complexity is that many emission reductions were achieved in the 1970s and early 1980s, and few new programs have been instituted since then to go beyond those control levels. While many new large emission sources are controlled via NSPS, providing consistent reductions throughout the United States, the operation and control of pre-NSPS units have a significant effect on emission trends. Since existing unit regulations emphasize solving nonattainment problems, regulations can be state-, county-, or even plant- or source-specific. All of the above serve to make future emission trend estimation a complex task.

Economics also have an important effect as declines in commodity prices and foreign competition in the 1980s have adversely affected industrial production levels in a number of mineral production and heavy manufacturing sectors, resulting in reduced air emission levels, with copper smelters and iron and steel mills being the best examples. Fuel and capacity utilization choice decisions in the utility and industrial sectors have also been affected by electricity demand and price differences among coal, oil, and gas.

U.S. REGIONAL EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

Pollutants and regions dominated by large point sources show the most year-to-year variation in emission levels. Dominant point source categories include electric utilities and copper smelters.

Significance of New Information

Regional emission patterns often follow national trends, but there are exceptions which must be noted when source-receptor relationships are explored for particular geographic areas or regional concerns. For example, U.S. regions bordering eastern Canada have experienced reductions in SO_x emissions from 1980 to 1985 consistent with the nation as a whole, while a copper smelting region in the southwest experienced a much larger SO_x emission reduction.

Explanation for Change

All federal regions had SO_x emissions decreases from 1980 to 1985, except Regions 6 and 8. Total reductions of SO_x from 1980 to 1985 were highest in Regions 3, 4, and 5, but these were also the highest SO_x emitting regions in 1980. Consequently, they all reduced their SO_x emissions at about the same rate as the national average in this period. Regions 2 and 9 had the largest percentage declines in SO_x, both about 25 percent. Region 9 decreases were primarily due to production declines at copper smelters.

Regional NO_x emission trends from 1980 to 1985 were generally downward in the eastern United States and either flat or upward in the west. Control regulations for NO_x are not as prevalent as they are for other pollutants, so, except for mobile sources, NO_x emissions track almost directly with fuel use. Regional highway vehicle emission trends were similar to those observed nationally, with regions having the highest VMT growth showing the least decline in emissions.

Regional VOC emission trends all seem to be similar to those observed at the national level. This lack of regional variation results from both the absence of dominant source types and the uncertainty in estimating VOC emissions.

CANADIAN EMISSION TRENDS FROM 1970 TO 1984

New Information Since 1983

Data on eastern Canadian emissions of SO_x (20 percent of U.S. levels in 1980) show that emissions decreased 44 percent between 1970 and 1984; U.S. emissions decreased 24 percent during this time period. Eastern Canadian emissions of NO_x, which were 8 percent of U.S. levels in 1980, increased by 29 percent between 1970 and 1984, with most of this increase occurring by 1974. U.S. NO_x emissions increased by 9 percent from 1970-1984.

Significance of New Information

The significance of this new information is that it provides a useful historical perspective between trends of U.S. and Canadian emissions that could contribute to transboundary transport of acidic air pollution.

Explanation for Change

Data on eastern Canadian emission trends (presented in Figure 45) show a 44 percent decrease in SO_x during the 1970-1984 time period and a 29 percent increase in NO_x emissions during the same period. SO_x emissions in eastern Canada generally decreased until 1984, when emissions from non-ferrous smelters rose 31 percent (from 1982 levels) as production increased. Smelters have historically accounted for over 50 percent of SO_x emissions in Canada, with utilities contributing about 20 percent. The relative contribution of smelters has been decreasing since 1970, while utilities' contribution has increased. NO_x emissions in eastern Canada have remained relatively constant since the mid-1970s, when transportation sector emissions stabilized.

U.S. UTILITY SO_x EMISSION TRENDS

New Information Since 1983

Emissions from coal-fired utility boilers decreased by 4 downward in the eastern United States and either flat or upward in the west. Control regulations for NO_x are not as prevalent as they are for other pollutants, so, except for mobile sources, NO_x emissions track almost directly with fuel use. Regional highway vehicle emission trends were similar to those observed nationally, with regions having the highest VMT growth showing the least decline in emissions.

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U.S. UTILITY SO_x EMISSION TRENDS

New Information Since 1983

Emissions from coal-fired utility boilers decreased by 4 percent from 1980 to 1985, while total U.S. SO_x emissions decreased about 11 percent. Much of this reduction was achieved between 1980 and 1982.

Significance of New Information

Throughout the study period, SO_x emissions were dominated by electric utilities, with major emitters being coal-fired boilers. SO_x emissions from utilities ranged from 66 to 68 percent of the U.S. total. In key eastern States bordering Canada, the utility share averaged 80 percent of the total. Although utility SO_x emissions have declined in recent years, an increase in the use of higher sulfur coal or uncontrolled utility boilers could rapidly reverse this decline.

Explanation for Change

Coal use by utilities was about 22 percent higher in 1985 than in 1980. Despite this, coal-fired SO_x emissions declined by about 4 percent during this time. These emission decreases, despite increases in potential emissions, were due to two factors: use of lower sulfur coals, and increased use of flue gas desulfurization (FGD) systems. Use of lower sulfur coal reduced 1985 emissions by about 2.4 million metric tons per year, while increased FGD usage resulted in further reductions of 1.4 million metric tons.

Increased low sulfur coal usage reuslts from a combination of factors including (1) growth in electrical demand in areas having ready access to low sulfur coals, (2) increased market penetration of low sulfur coals, and (3) environmental regulations. In the future, coal market forces could reverse the current tendency to use low sulfur coal.

Utility emissions decreased during 1980-1985 due to a combination of economic and regulatory factors. EPA's pre-1983 analysis of future electric utility emission trends indicated that these trends would be primarily a function of two parameters: (1) the replacement of existing sources with new sources subject to NSPS, and (2) the rate of construction of such new facilities. Current analysis of 1980-1985 emission trends indicates that capacity utilization of existing utility boilers has a significant effect on emission levels. For the last several years, utility capacity utilization has been depressed for a number of large eastern utility plants. These are predominantly burning medium-to-high sulfur content coals with no SO_x controls. Possible future increases in the use of these plants to meet increased electricity demand could produce increased emissions.

THE INFLUENCE OF STACK HEIGHT ON THE TRANSPORT OF EMISSIONS

New Information Since 1983

Since 1983, work has begun to distinguish and quantify the difference between emissions released close to the ground and emissions released at higher elevations through "tall stacks." This analysis indicates a significant increase in the tonnages of SO_x emissions released through tall stacks between 1950 and 1980.

While the phrase "tall stacks" refers to not only stack height but also to increased flue gas exit velocity and temperature, the data presented here are limited to physical height only.

Significance of New Information

The significance of emission trends must be balanced by an understanding of the fate of the emissions. Although emission trends analysis indicates an historic decrease in SO_x emissions, this decrease may be counterbalanced by an increase in the amount of SO_x emitted through tall stacks and thus more directly available for long-range transport.

Explanation for Change

Increases in physical stack height and in emission stack parameters such as flue gas temperature and exit velocity increase the height to which emission plumes rise. This increases the potential for long-range transport of emissions. For example, in 1980, approximately 30 percent of SO_x emissions were from stacks taller than 240 feet, compared with only 5 percent above this height in 1950. These stack height, temperature, and velocity increases have been made largely to reduce peak concentrations near major emission sources to meet ambient air quality standards whithout controlling the quantity of SO_x emitted. Comprehensive information on stack height changes since 1980 is not currently available, but when the 1985 NAPAP emissions data base is completed later this year, an analysis of stack height changes from 1980 to 1985 can be performed.

U.S. NO_x EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

There is no demonstrable trend in national NO_x emissions between 1980 and 1985. However, recent estimates of highway vehicle NO_x emissions (which constitute 45 percent of national NO_x emissions) indicate a possible increase in these emissions during 1986 and 1987.

Significance of New Information

This is a change from pre-1983 projections that national NO_x emissions would decrease as highway vehicle emissions decreased. It was thought that transportation sector decreases, the result of increasingly stringent NO_x emission standards, were expected to more than offset any NO_x emission increases from utility and industrial sector fuel combustion.

Explanation for Change

The major contributors to NO_x emissions are highway vehicles (45 percent) and utilities (33 percent). National highway vehicle emission trends show a decline from 1980 through 1982 or 1983 with an upward trend starting in 1984. Utility NO_x emissions followed a similar trend. However, in relation to the methodological uncertainty inherent in the emissions trends analysis for NO_x, there is no observable trend in national NO_x emissions during the 1980-1985 time period.

NO_x emissions from transportation sources, primarily highway vehicles, were expected to decrease by 9 percent in the 1980-1990 time period before beginning to increase again after 1990. Recent estimates of vehicle miles traveled, age, and emission rates suggest that an upturn in NO_x emissions from the transportation sector may have begun in 1984. VMT of light and medium duty trucks have increased significantly over the past few years as these vehicles have gained in popularity. Because NO_x emissions from these trucks are less tightly controlled than highway vehicle emissions, increases in truck VMT translate directly into NO_x emission increases.

U.S. VOC EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

VOC emissions declined only about half as much as earlier projections for this time period indicated.

Significance of New Information

The United States Environmental Protection Agency estimates of VOC emissions prior to 1983 appear to have overestimated the reduction in emissions that would be achieved in response to control programs.

Explanation for Change

Previous expectations were that total national VOC emissions would decline by 18 percent from 1980 to 1990, and that transportation-related VOC emissions might decline by 50 percent during this time period. However, the VOC emission trends between 1980 and 1985 indicate that total and transportation sector emissions declined by 7 and 12 percent, respectively. Lack of significant declines in the transportation-sector-emitted VOC has resulted from more rapid than expected VMT growth, increased popularity of less well controlled new vehicles, and slower than expected vehicle turnover. It should be noted that VOC emission estimates are more uncertain than those for SO_x and NO_x.

EMISSIONS IN THE NEAR FUTURE

New Information Since 1983

Preliminary fuel consumption data for 1986 and the current relationship among coal, oil, and gas prices indicate that emissions of SO_x, NO_x, and VOC are not expected to vary significantly from 1985 levels during 1986 and 1987, although SO_x emissions may decrease slightly.

Significance of New Information

The flat trajectory that SO_x, NO_x, and VOC emission trends followed in the mid-1980s may indicate that without additional control initiatives, future (1990) emissions of all these pollutants will be higher than they are now if fuel use and VMT increase.

Explanation for Change

Electricity generation in the first seven months of 1986 was relatively close to 1985 levels, while coal production (80 percent of which is consumed by utilities) through November 1986 was within 1 percent of 1985 levels. These are key indicators that 1986 SO_x emission levels will be close to 1985 values. In the absence of major changes or disruptions in relative fuel economics, 1987 U.S. utility coal consumption is likely to be within 5 percent of 1985 levels, foretelling a relatively small change in SO_x emissions.

The source category with the biggest influence on future NO_x and VOC emissions is transportation. With the trends in NO_x and VOC emissions observed from 1980 to 1985, there is little reason to expect that emissions from highway vehicles will decline in the near future. Only gasoline shortages or much higher fuel prices, which would reduce VMT growth, would provide highway vehicle emission reductions given the current emission standards.

SECTION 1

INTRODUCTION

The purpose of this project was to examine trends in acid deposition precursor emissions from 1980 through 1985. Emission trends in the 1980s have important implications for future EPA policy as potential control efforts need to take into account how emissions are changing by source emitting sector and region.

Because acid deposition is an international issue and U.S. source emissions may impact Canadian receptors and vice versa, summary information on eastern Canadian emissions from 1970 to 1984 is also presented in this report.

The methods used here to produce regional emission trend data rely heavily on EPA's published national emission Trends reports, which primarily use national level fuel combustion or production values, emission factors, and average levels of pollution control to estimate national emissions. The national level SO_x, NO_x, and VOC estimates provided in this report agree with those published recently by EPA. In large part, the methods used in this study to provide regional emission estimates by pollutant and source category are similar to those of the Trends reports, except that state or regional production indicators are used instead of national ones. For the most important source categories for SO_x, electric utilities and copper smelters, plant level data are employed to provide regional emission trend estimates.

It should be recognized that an analysis using Trends type methods may produce different results than would be obtained by using source-specific data and aggregating them to regions. If data equivalent to those in the 1980 National Emissions Data System (NEDS)/National Acid Precipitation Assessment Program (NAPAP) Emission Inventory were available for all analysis years, they would be used in this study. Unfortunately, these data sets do not exist. The 1985 NAPAP Emission Inventory is being compiled at this time and is designed to meet the various needs of acid deposition researchers, but there are no similar data sets for the intervening years. The Trends type methodology provides a means for estimating yearly emission changes on a national or regional basis that is not easily handled by a detailed source inventory. On the other hand, detailed source inventories such as the 1980 or 1985 NAPAP efforts are needed periodically to meet the needs of atmospheric transport models and economic simulation models.

SECTION 2

SUMMARY OF NATIONAL EMISSION TRENDS

AGGREGATE RESULTS

In the year-to-year periods covered by the six years from 1980 to 1985, emissions of all three of the pollutants considered in the study have shown both declines and increases. Figure 1 shows these trends for each pollutant measured in terms of absolute emissions. The most pronounced decline was for SO_x, which experienced an overall net decline of almost 11 percent for the entire six year period. Declines in VOC emissions were less than half that while the decline in NO_x emissions between 1980 and 1985 is insignificant when compared to potential inaccuracies in the analysis methods and results. Note that in order to make the presentation of results consistent, all emissions of sulfur compounds, (e.g., SO_2, $SO_4^=$), have been converted to equivalent quantities of SO_2 and are reported as SO_x. For nitrogen compounds, a similar procedure was used, all values were converted to equivalent quantities of NO_2, and the results are reported as NO_x.

Figure 2 shows SO_x, NO_x, and VOC emission trends on a relative basis along with similar data for (GNP) and population (Census, 1985). These figures show that emissions have declined while both population and GNP have increased. Interestingly, while GNP showed a dip in 1982, emissions of both SO_x and NO_x continued to decline, reaching their lows over the six year period in 1983. For VOC, 1982 was the low point in emissions.

To put the results of this analysis into better context, Figure 3 shows longer term trends in emissions along with real GNP. These emission estimates are taken from the Trends report (U.S. EPA, 1986b). The emissions from 1940 through 1970 are reported at ten year intervals and from 1970 through 1985 at five year intervals. Values for intervening years are interpolated. These results agree with other research including a study by Gschwandtner et al. (1986) which estimated SO_x and NO_x emissions as far back as 1900. From 1940 until the mid-1970s, emissions generally moved with GNP. The slight decline in SO_x emissions between 1950 and 1960 was due to an absolute decline in coal use between these two years. During this period, use of oil and natural gas was increasing rapidly, resulting in market share loss for coal which was not reversed until the 1960s. Clean Air Act effects (post 1970) are apparent for each of the pollutants.

The potential for long-range transport of emissions is dependent on several stack parameters. The height to which emission plumes rise is determined by physical stack height and by flue gas temperature and exit velocity. Current analyses of plume rise have accounted for only the effect of stack height. Figures 4 and 5 show the overall trend of SO_x and NO_x emissions

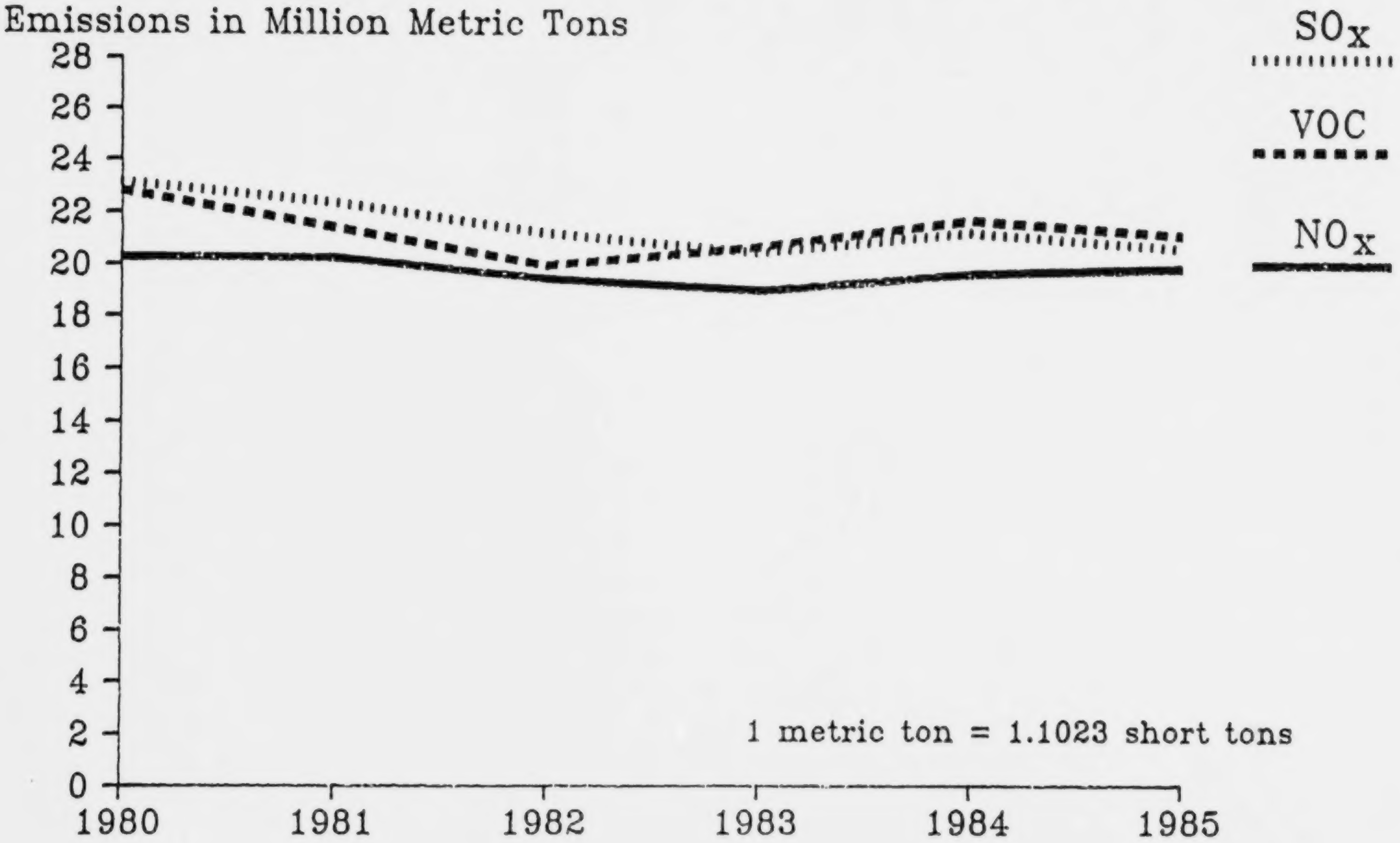


Figure 1. United States emission trends (1980–1985).

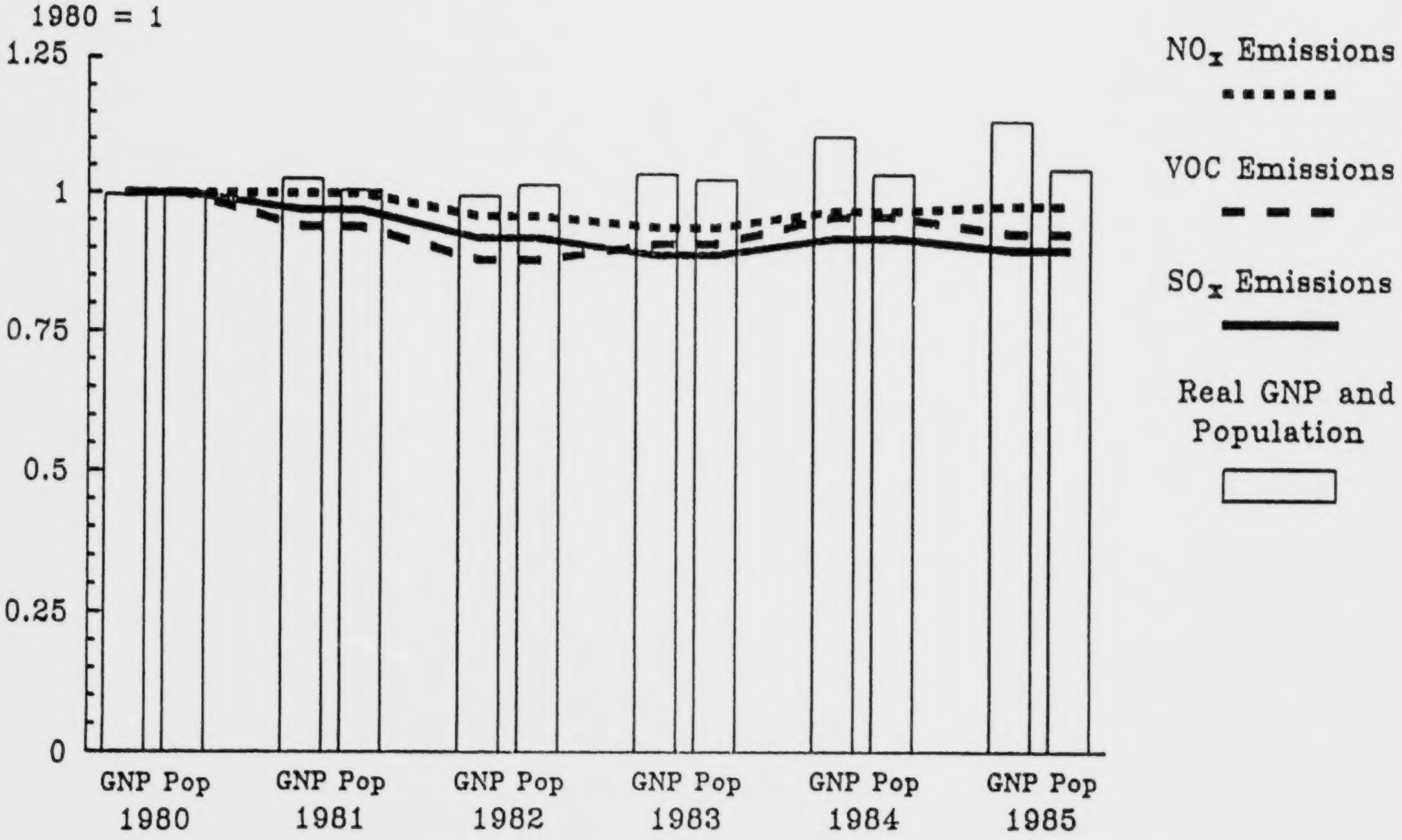


Figure 2. United States emission and economic variable trends (1980–1985).

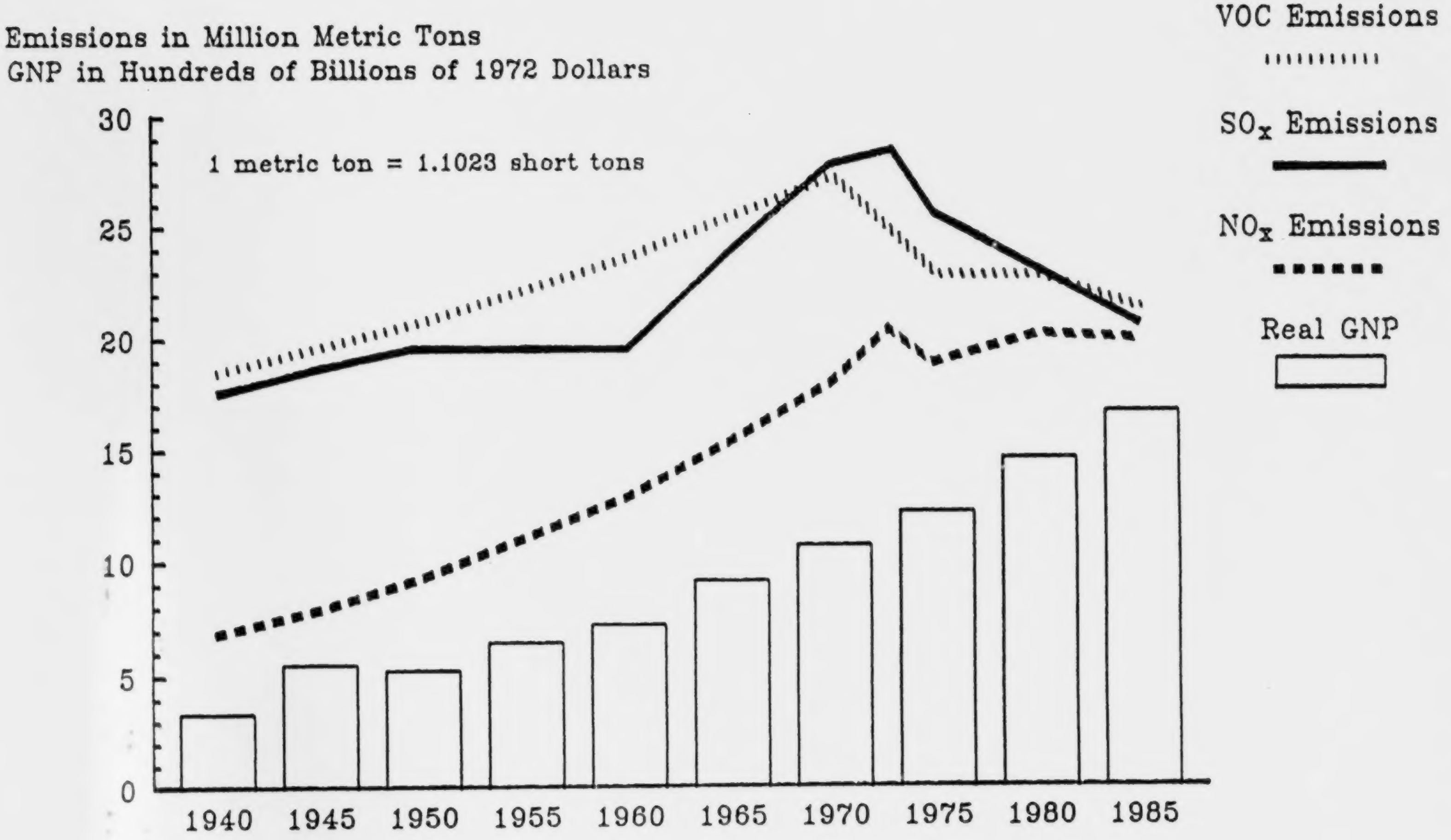


Figure 3. United States emission and GNP trends (1940–1985).

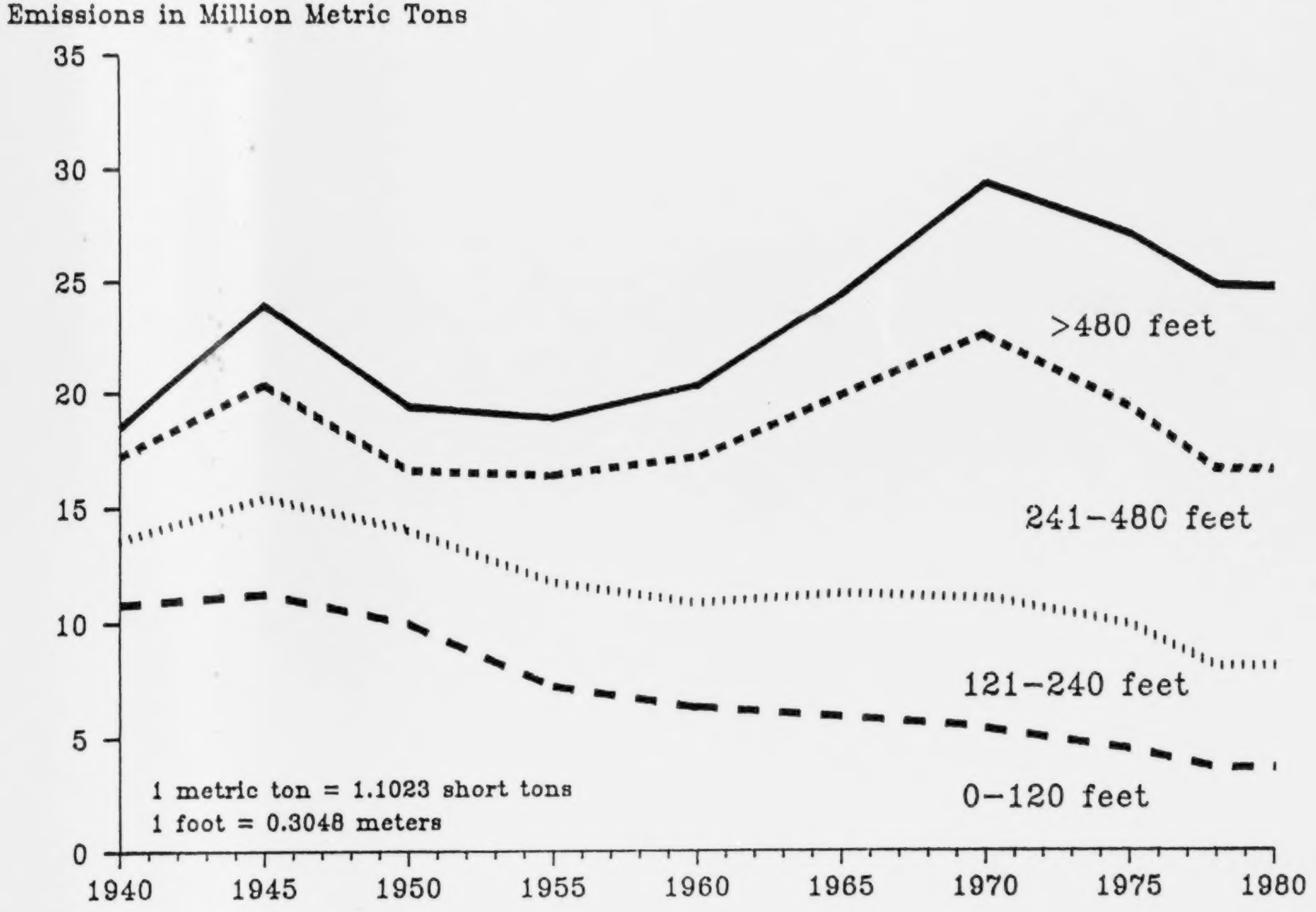
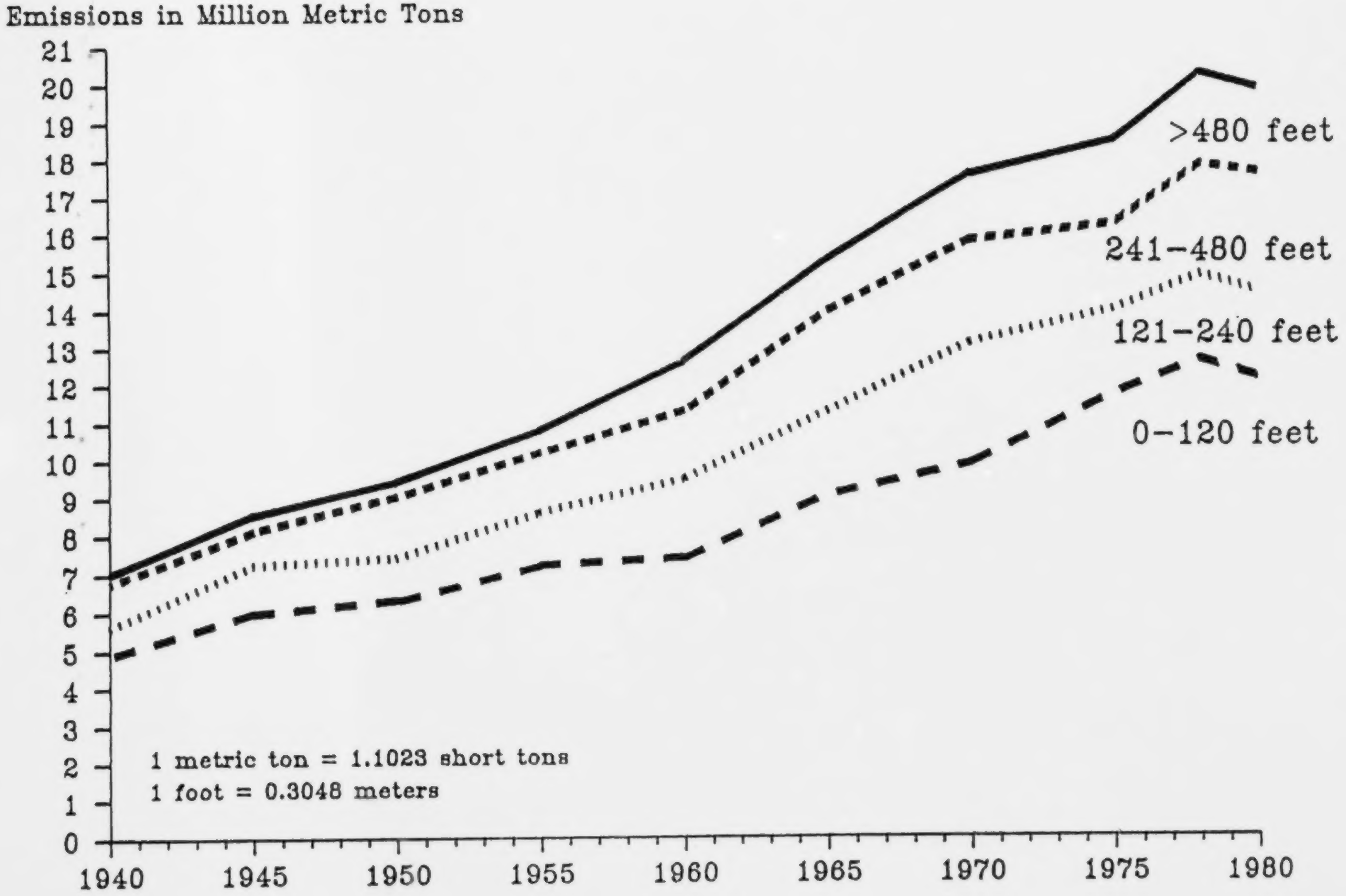


Figure 4. United States SOx emission trends by stack height range (1940-1980).



1 metric ton = 1.1023 short tons
1 foot = 0.3048 meters

Figure 5. United States NOx emission trends by stack height range (1940-1980).

by stack height from 1940 to 1980 (Gschwandtner et al., 1986). By 1980, approximately 30 percent of SO_x emissions were released above 480 feet, whereas only 5 percent were emitted at this height in 1950. The percentage of total SO_x emissions released below 120 feet has generally decreased over time. The distribution of NO_x emissions has historically remained constant, although national emission totals have steadily increased. The tendency toward increased stack heights is especially apparent in the electric utility industry, significantly affecting the overall distribution of emissions by stack height. Stack height, temperature, and velocity increases have been made largely to reduce peak concentrations near major emission sources to meet ambient air quality standards without controlling the quantity of SO_x emitted.

These results covering the 1980-1985 period combined with those from earlier years demonstrate that contemporary changes in emissions are not coupled in a simple direct fashion to aggregate measures of economic activity. Prior to the development of control programs in the 1970s, emissions tended to increase over time in conjunction with measures of broad economic activity such as GNP. After the mid-1970s, on the other hand, year-to-year declines in emissions occurred despite changes in levels of economic activity. Results from the current study indicate that neither control programs, which tend to reduce emissions, nor increases in economic activity, which produce emissions, are consistently dominant. These themes are explored in more detail in later sections of this report.

Man-made emissions, the focus of this report, exceed air emissions from natural sources of sulfur and nitrogen compounds. For sulfur compounds, natural sources in the United States are estimated at 0.9 million metric tons SO_x (Fehsenfeld, 1986) compared to 23.2 million metric tons from man-made sources. Natural source NO_x emissions are estimated at 3.4 million metric tons (U.S. EPA, 1986a) compared to 20.3 million metric tons from man-made sources. For VOC, only rough estimates are available of natural source emissions, although they are likely to be significant in total tonnage relative to total man-made emissions (Zimmerman et al., 1978). The uncertainty of these estimates is compounded by the vastly different atmospheric reactivities of different species of natural VOC emissions. In general, natural source emission estimates are much more uncertain than estimates of man-made emissions.

EMISSIONS CHANGES BY CATEGORY

The summary data presented above suggest that analysis of emissions trends requires investigation of specific categories of economic activity since the amount of pollution generated per dollar contributed to GNP can differ significantly, depending upon the specifics of the activity. In this section, emission-producing activities have been divided into four broad categories to show, in general, which economic activities account for the majority of each of the three pollutants considered in this study.

The four broad source categories selected are electric utilities, industrial (primarily manufacturing) activities, transportation, and all other sources. The significance of each of these major categories to overall emissions of each pollutant is discussed below along with some insight into which subcategories are responsible for significant shares of category emission totals. Figure 6 illustrates the average shares by broad source categories for the years from 1980 through 1985.

Throughout the period of this study, emissions of SO_x were dominated by electric utilities and, within this category, by combustion of coal at steam-electric plants. The utility share of SO_x emissions ranged from 66 to 68 percent during this time period, a negligible range of difference. The majority of the remaining SO_x emissions is accounted for by industrial activities. These activities accounted for 25 to 27 percent of total emissions, leaving less than 10 percent for all other activities. Predominant industrial sources were combustion of coal and emissions from heavy manufacturing processes such as ore smelting, petroleum refining, and cement production. Figure 7 displays these results graphically.

Figure 8 shows NO_x emissions by category over the study period. Electric utilities also contribute significantly to emissions of NO_x, but not to the extent that they dominate SO_x. For the nation as a whole, the utility share of NO_x during the study period ranged from 31 to 34 percent, again, a very small variation over the six year study period. Transportation sources, primarily highway vehicles, accounted for 44 to 46 percent of total NO_x emissions. Of this amount, the share associated with highway vehicles was about 80 percent. Industrial fuel burning, predominantly natural gas combustion, accounted for 13 to 14 percent of national NO_x emissions during the 1980 to 1985 period.

For VOCs, the majority of emissions result from either evaporative losses or incomplete combustion of fuels; those resulting from incomplete combustion of fuels, as indicated below, were primarily associated with mobile sources and residential wood combustion. Since fuel combustion by electric utilities is accomplished at high temperatures and burning is relatively complete, the utility sector is an insignificant source of VOC emissions despite the fact that it accounts for a substantial share of total combustion. Figure 9 illustrates the VOC emissions by category over the study period.

The largest share of VOC emissions was associated with industrial activities, accounting for about 40 percent of all VOC emissions. The major contributing subcategories included surface coating, oil processing, oil refining, and petroleum product storage. At the national level, the source category with the

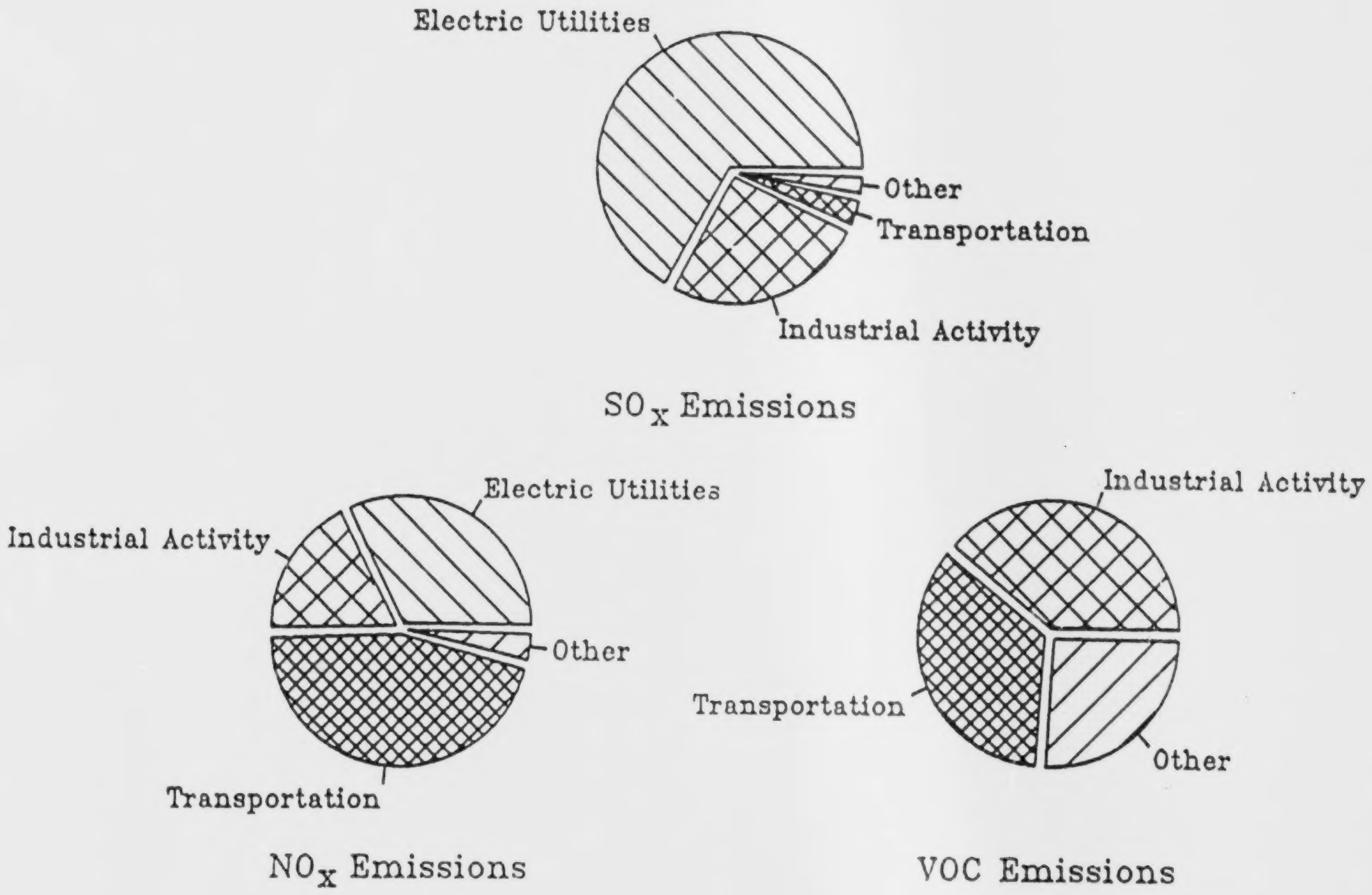
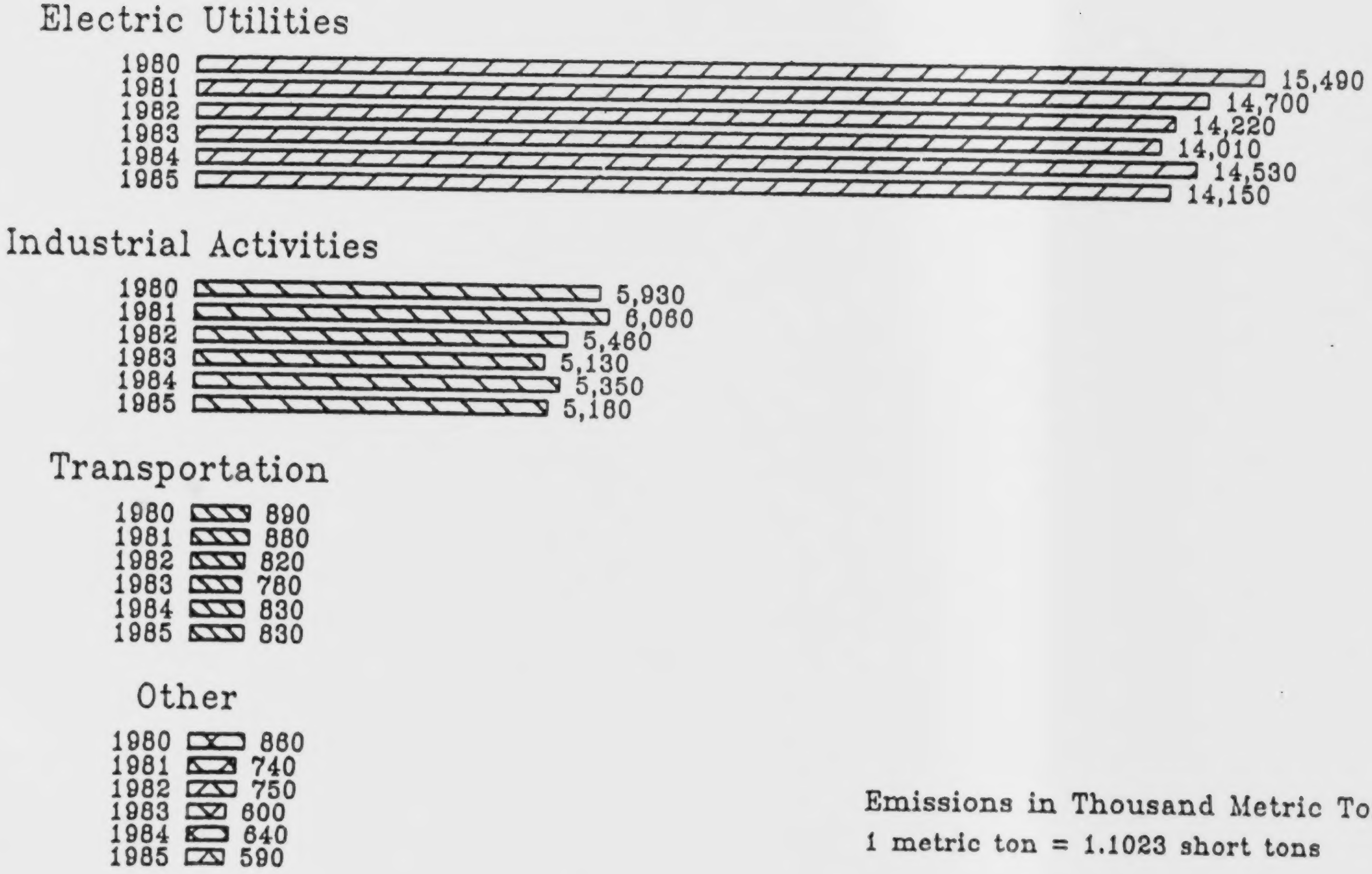
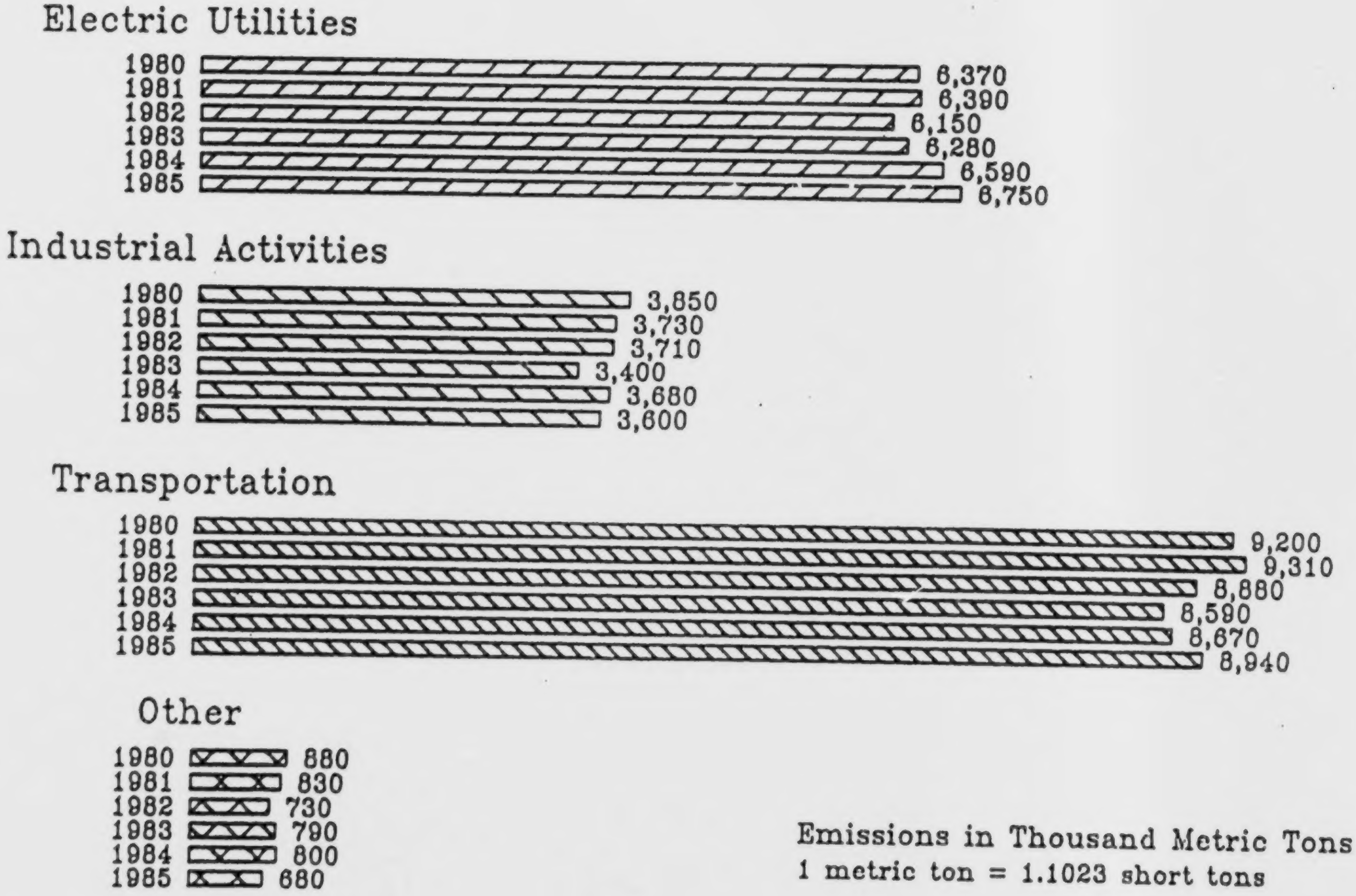


Figure 6. United States emission shares by source category (average for 1980–1985).



Emissions in Thousand Metric Tons
1 metric ton = 1.1023 short tons

Figure 7. United States SOx emission trends by source category (1980–1985).



Emissions in Thousand Metric Tons
1 metric ton = 1.1023 short tons

Figure 8. United States NOx emission trends by source category (1980–1985).

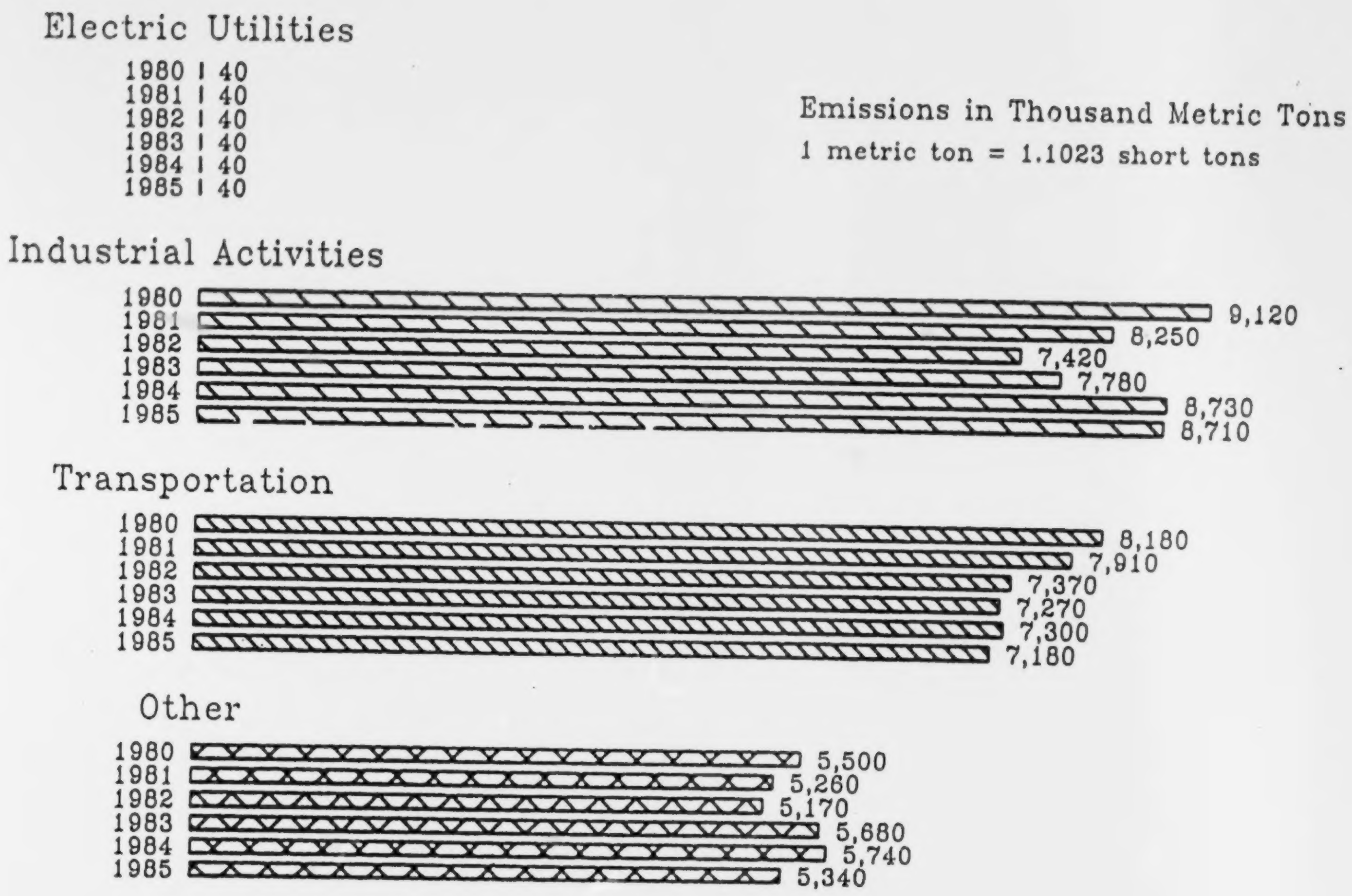


Figure 9. United States VOC emission trends by source category (1980–1985).

greatest variation in year-to-year VOC emissions was surface coating. National surface coating emissions decreased by 33 percent from 1980 to 1982 and then increased to 5 percent above 1980 values by 1985. This variation was due in large part to changes in industrial production of manufactured products and the associated consumption of organic solvents. Lower industrial production in 1982 and 1983 produced a corresponding change in solvent consumption. As with utilities, fuel combustion in industrial facilities is relatively complete and, hence, does not result in a large quantity of VOC emissions.

Volatile organic compounds from transportation sources, however, are significant. Over the six year study period, this category accounted for 34 to 37 percent of VOC emissions. More than 80 percent of the category total was due to highway vehicles.

About one-fourth of VOCs were placed in the "other" category. Within this category, almost half of the VOC emissions were due to residential wood combustion (or about 10 to 12 percent of total VOC from all sources). The rest of the emissions in this category were due primarily to miscellaneous sources including forest fires, other burning, and solvent use not otherwise accounted for. Residential wood combustion produces a large quantity of unburned VOCs due to relatively low combustion temperatures, poor mixing of fuel and air, and relatively poor combustion controls.

CANADIAN EMISSION TRENDS

Current Emission Levels

Of particular interest to U.S. policy analyses are SO_x and NO_x emissions in eastern Canada (provinces east of the Saskatchewan/Manitoba border). Emissions of these pollutants from 1970 to 1984 are graphically illustrated in Figure 10. These trends data show a 44 percent decrease in SO_x emissions and a 29 percent increase in NO_x emissions for this time period (Vena, 1987).

Legislative emphasis on the measurement and decrease of emission levels was initiated by the various provincial and municipal governments in the late 1960s and early 1970s. As a result, SO_x emissions decreased, and NO_x emissions increased less than would have otherwise been expected.

Emissions data available for the eastern Canadian provinces fall into four major source categories:

- Industrial Processes
- Fuel Combustion/Stationary Sources
- Transportation
- Miscellaneous

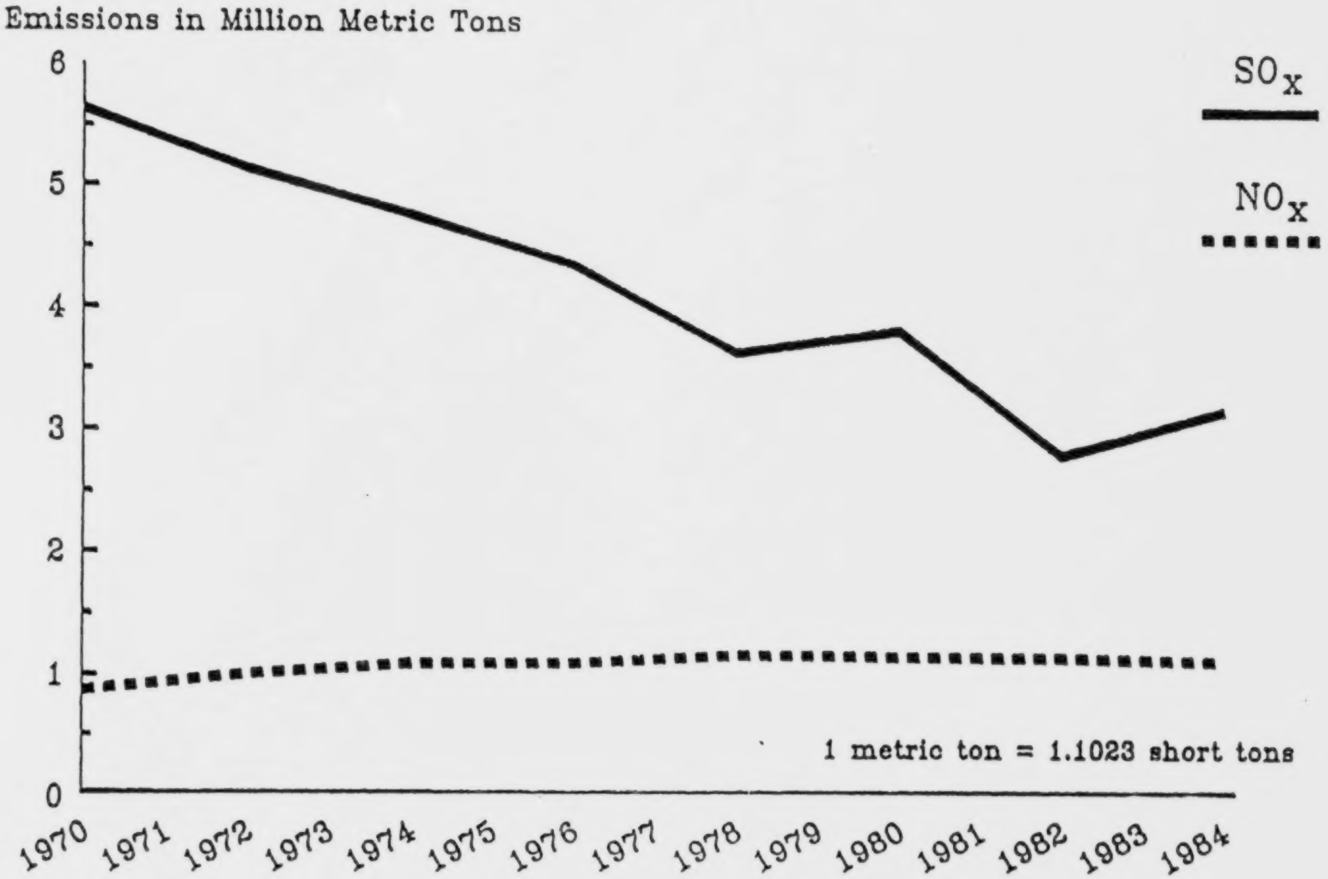


Figure 10. Eastern Canada SOx and NOx emission trends (1970–1984).

Unlike the United States, electric utilities contribute only about one-fifth the total SO_x emissions, while nonferrous smelters contribute over 50 percent. As in the United States, transportation sources dominate NO_x emissions. Figure 11 illustrates the average contribution of each of the major categories to SO_x and NO_x emissions from 1980 to 1984.

Eastern Canadian SO_x emissions from each source category since 1974 are shown graphically in Figure 12. The SO_x emissions reduction is largely due to the reduction in emissions in the nonferrous smelting sector -- from 2.9 million metric tons in 1974 to 1.8 million metric tons in 1984. Although the emissions due to utility power generation rose during the same period, this was more than offset by a reduction in emissions due to residential, commercial, and industrial fuel combustion.

Figure 13 shows NO_x emissions by major source category since 1974. Transportation sources dominate NO_x emissions, with light-duty vehicles contributing 42 percent of the transportation total. After an increase in NO_x emissions of about 25 percent in the early 1970s, primarily due to light- and heavy-duty vehicles and other diesel mobile equipment used in forestry, agriculture, construction, and mining, eastern Canadian NO_x emissions have remained relatively stable.

Future Emission Levels

The major sources of SO_x emissions in Canada are the industrial and fuel combustion sectors. Demand for nonferrous smelter production is currently declining and technological improvements adopted by the industry have reduced emissions. These economic trends, combined with a federal/provincial government SO_x control program, are expected to substantially reduce these SO_x emissions by the early 1990s. An additional reduction in SO_x and NO_x emissions from the utility sector is also expected as the percentage of electricity generated by nuclear plants increases and emissions from coal-fired utilities decrease. Conversely, transportation sector emissions of NO_x have been increasing because of increasing vehicle population. There is no apparent reason to expect this trend to change.

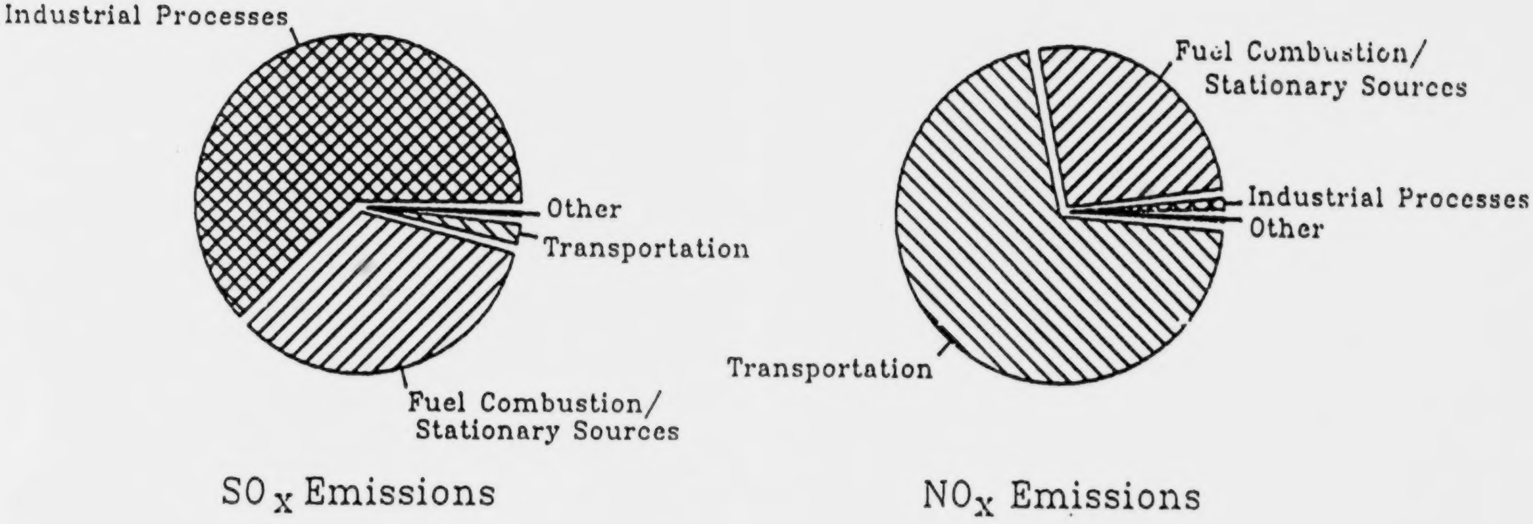


Figure 11. Canadian emission shares by source category (average for 1980–1984).

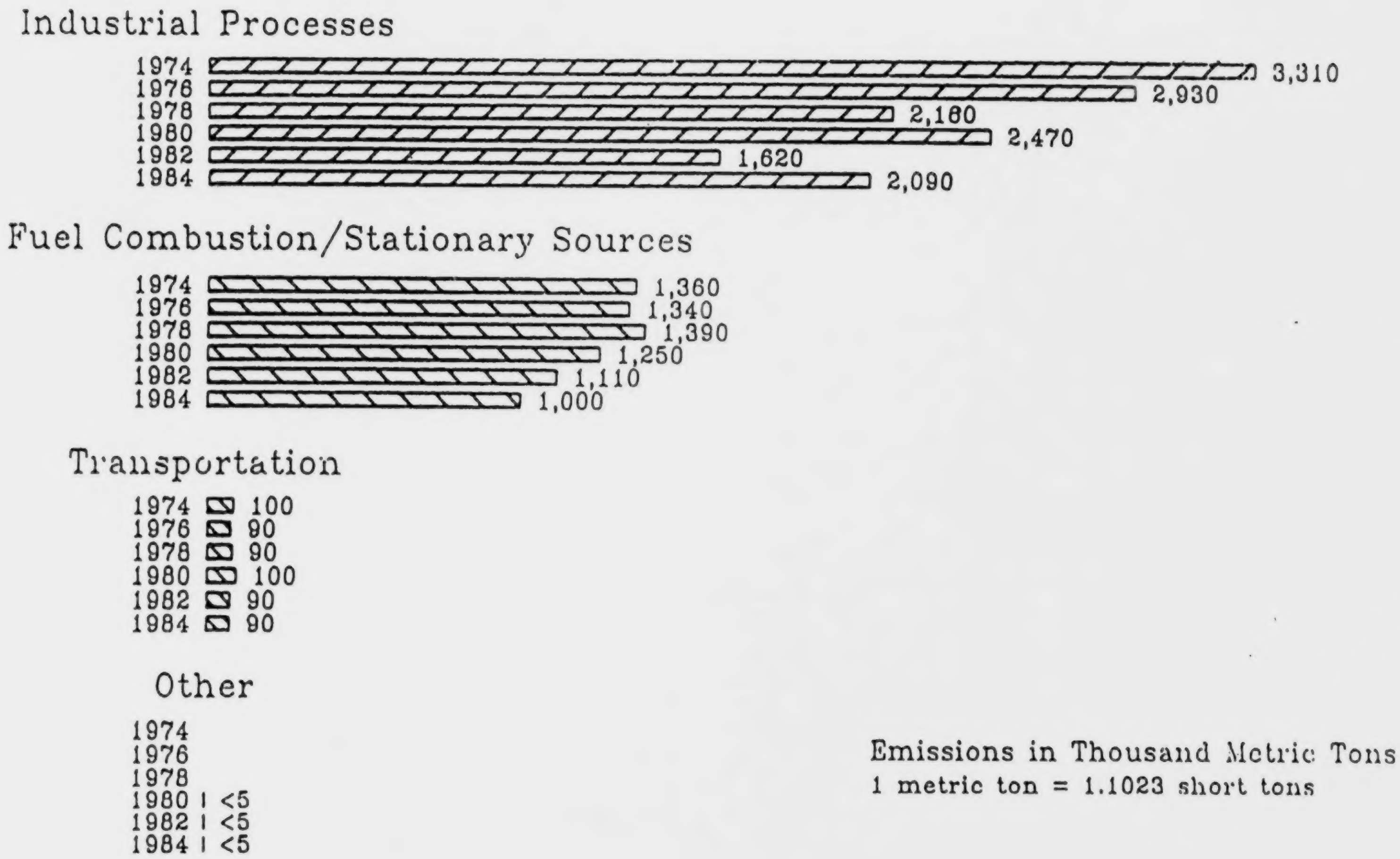


Figure 12. Canadian SOx emission trends by source category (1974–1984).

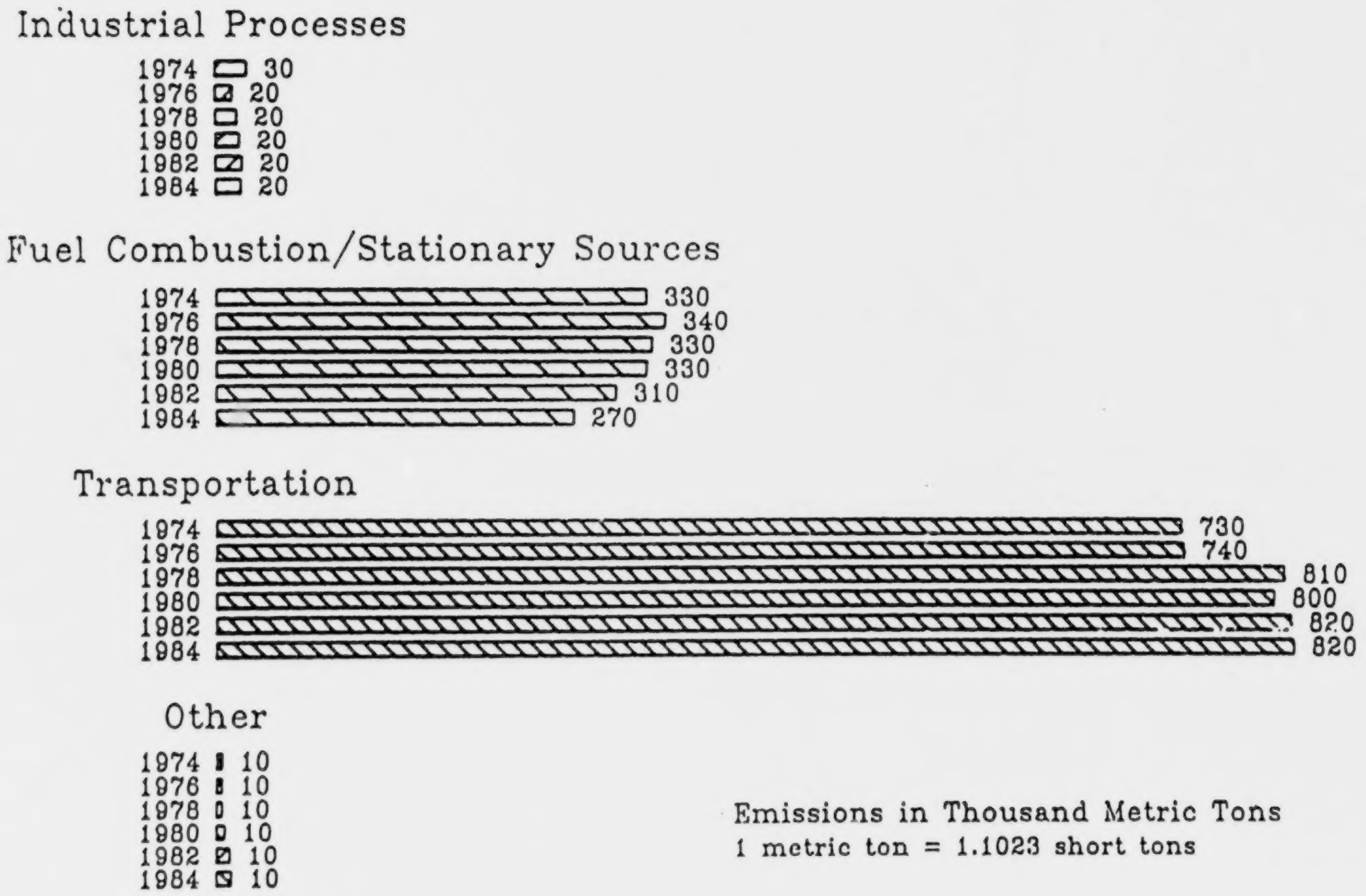


Figure 13. Canadian NOx emission trends by source category (1974-1984).

SECTION 3

SUMMARY OF OVERALL REGIONAL TRENDS

In this section, overall changes in emissions by region are discussed. The regions selected for analysis were the 10 Federal administrative regions used by EPA and other Federal agencies. Each of these regions is an aggregate of two or more states as shown in Figure 14. While the discussion in this section is limited to total emissions, the next section provides additional detail concerning which source categories were responsible for these changes.

REGIONAL TRENDS BY YEAR

Figure 15 shows overall trends in regional emissions for SO_x when emissions from all source categories are aggregated. In general, regional aggregate emission trends over the entire period followed those of the nation as a whole, with 1985 being lower than 1980 with some minor ups and downs between individual years. The regions showing the greatest declines in absolute terms were Regions 3, 4, and 5. These regions also had the highest emissions in 1980. Region 9 showed a large increase from 1980 to 1981, but this increase was more than offset by later declines in SO_x emissions resulting from reduced copper smelter operation. Only Regions 6 and 8 had higher SO_x emissions in 1985 than in 1980.

Figure 16 shows overall changes in regional emissions for NO_x. As was the case with SO_x, Regions 4 and 5 are among the highest emitting regions throughout the study period. Region 6, which had significantly lower SO_x emissions than Regions 4 or 5, had NO_x emissions almost as great. This difference is due primarily to the comparatively high use of natural gas in Region 6. This use of gas, particularly in process heat applications, results in significant NO_x emissions but almost no SO_x. Regions showing overall increases in NO_x emissions during the 1980-1985 time horizon were Regions 6, 8, and 9. Transportation sources have been a major contributor to NO_x emissions in Region 9.

As with NO_x, Regions 4, 5, and 6 are the predominant VOC emitters with Region 9 ranked fourth as illustrated in Figure 17. Industrial process sources and transportation both contribute to the high emissions and the year to year variations in these regions.

In addition to total annual emissions, a number of other variables have been suggested as having a major role in acidic deposition effects. These include the overall density of emissions over geographic regions, the effect of major sources, and temporal resolution. Although these variables are not a major focus of the present analysis, insights concerning the variation introduced by them are summarized below.

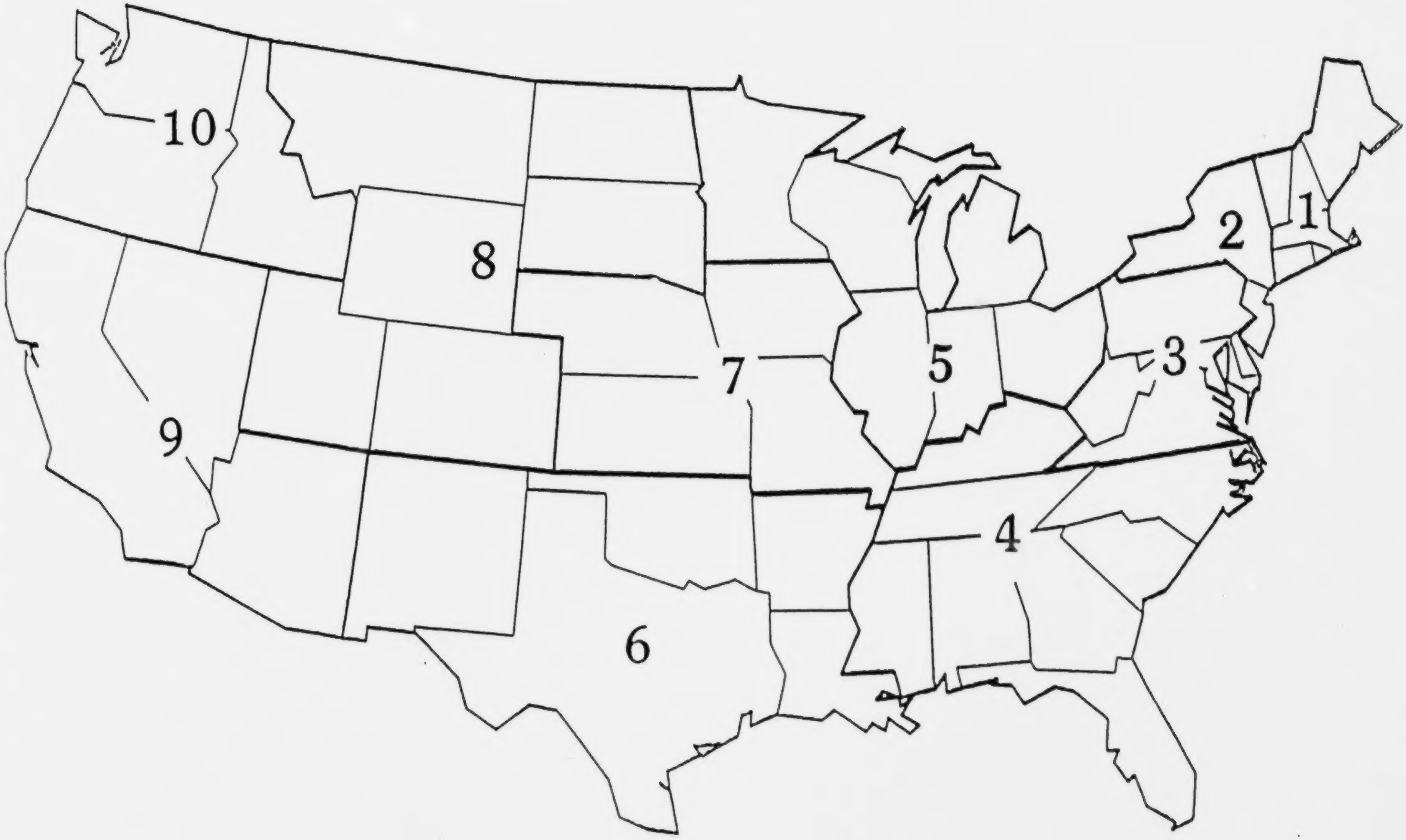

10
9
8
7
6
5
4
3
2
1

Figure 14. Federal Administrative Regions.

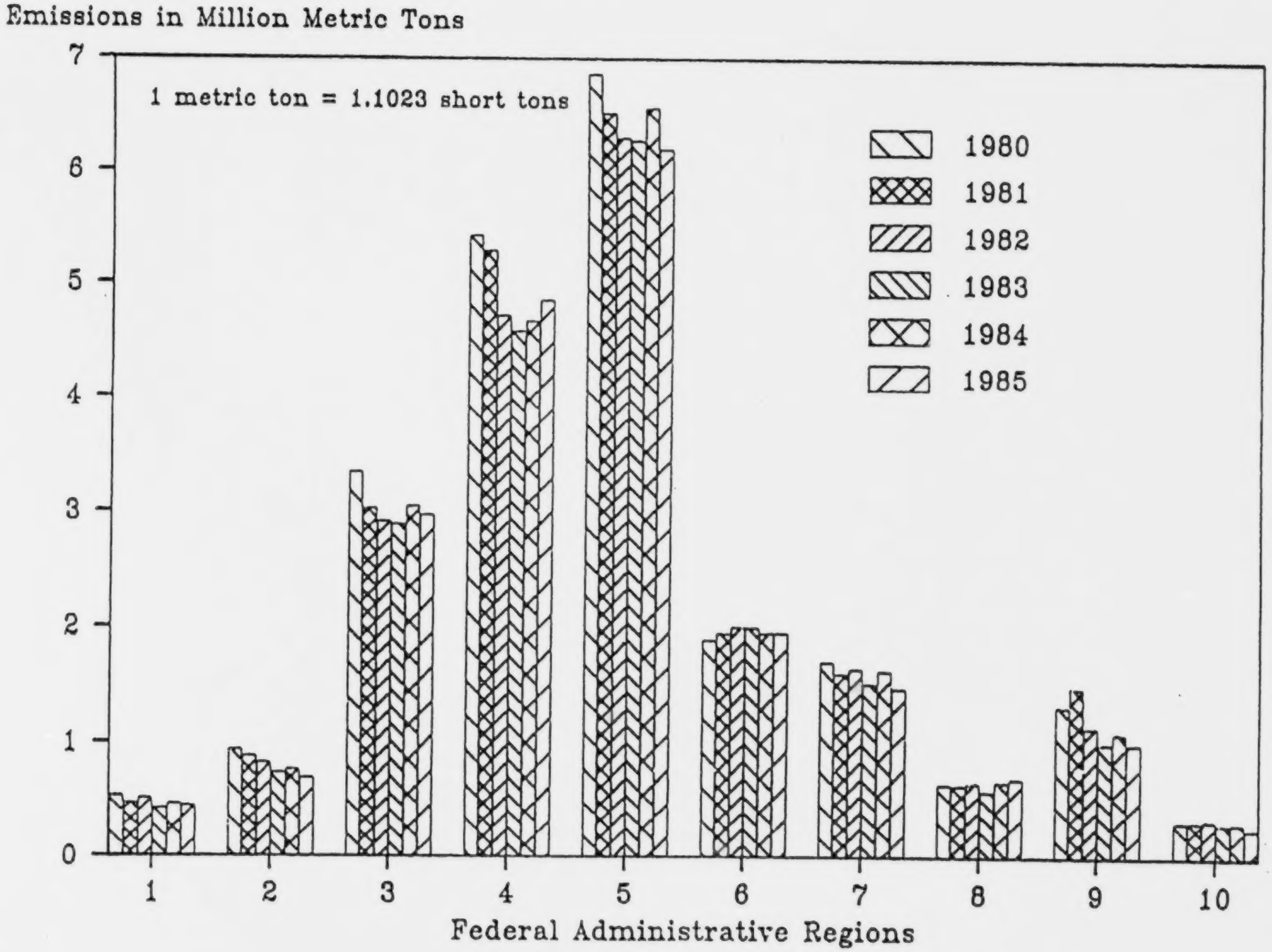


Figure 15. United States SOx emission trends by region (1980-1985).

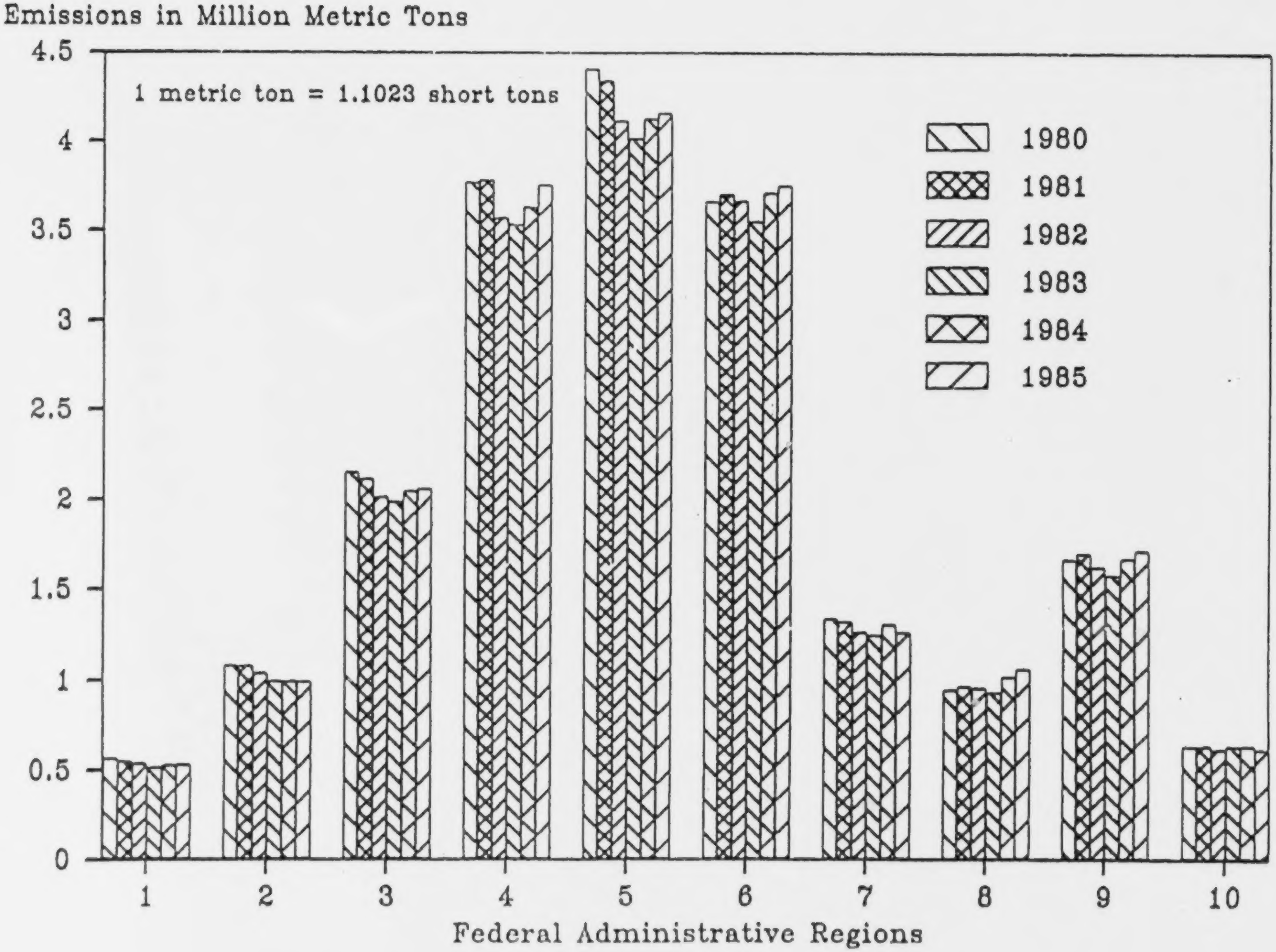


Figure 16. United States NOx emission trends by region (1980–1985).

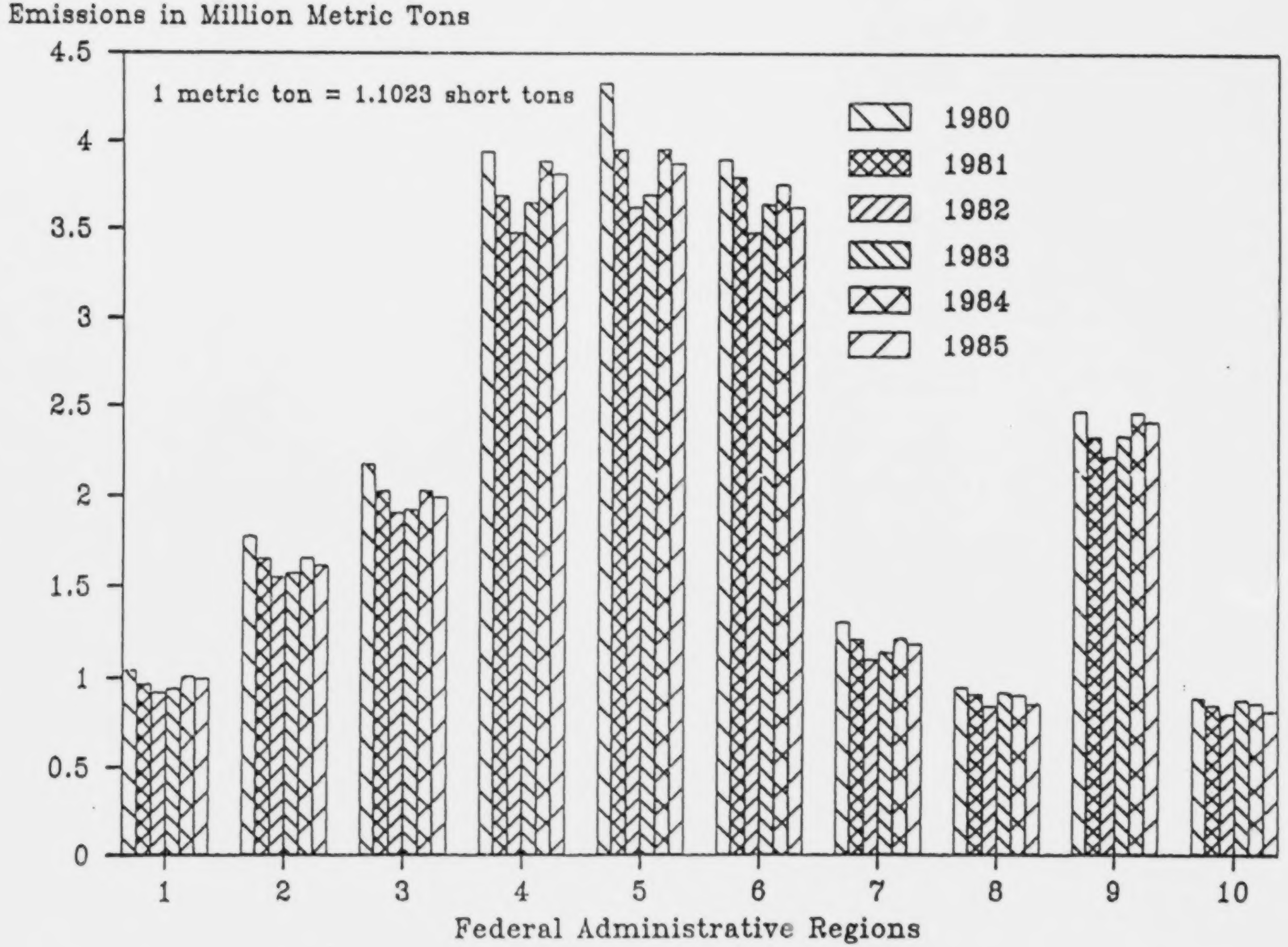


Figure 17. United States VOC emission trends by region (1980-1985).

EMISSION DENSITY

The overall density of emissions, measured in units such as kilograms per hectare (kg/ha), is an important variable in modeling deposition. For purposes of the present analysis, SO_x, NO_x, and VOC emission densities were calculated for each of the 10 Federal Regions.

Figures 18 through 20 show the average emission density for each region over the 1980-1985 time horizon. For all three pollutants, emission densities were higher in the eastern regions (Regions 1 through 5).

Region 3 had the highest SO_x emission density with a value of 97 kg/ha. This is due to the region's relatively high population and industrial activity and relatively small area. The second highest density was found in Region 5 (with a value of 77 kg/ha), due to the coal-fired utility power plants in the Ohio River basin. The highest western region emission density was in Region 7 with a value of 22 kg/ha. Regions 8 and 10 had the lowest average values, 5 kg/ha, due to large area and low population in the case of Region 8 and extensive use of hydroelectric power generating facilities in Region 10.

The influence of transportation sources is apparent in the emission density estimates for NO_x. The highest values are in the east with highly populated and urbanized Regions 2 and 3 having values of 72 and 66 kg/ha. Region 6 with 26 kg/ha had the highest density among western regions due, in large part, to natural gas combustion. Region 8 had the lowest NO_x emission density, 7 kg/ha.

The highest emission density for VOC was in Region 2 with 115 kg/ha, almost twice that of Region 3 (64 kg/ha) and Region 1 (60 kg/ha). Again, Region 8 had the lowest value (6 kg/ha).

In addition to the average density, estimates of emission density variation over the six year period were also made. These estimates, along with other data, may be of value in attempting to explain year to year changes in deposition. For this analysis, an average variation was estimated. First, the range between the highest and lowest emission densities over the period was calculated. This range, expressed as a percentage of the average emission density, is the emission density variation estimate used here.

Figures 21 through 23 show the variation in emission density for SO_x, NO_x, and VOC, respectively. On average, emission density variation is highest for SO_x and lowest for NO_x. This is due to the relatively large impact of major point sources on SO_x emissions.

The highest variation in SO_x emission density was in Region 9

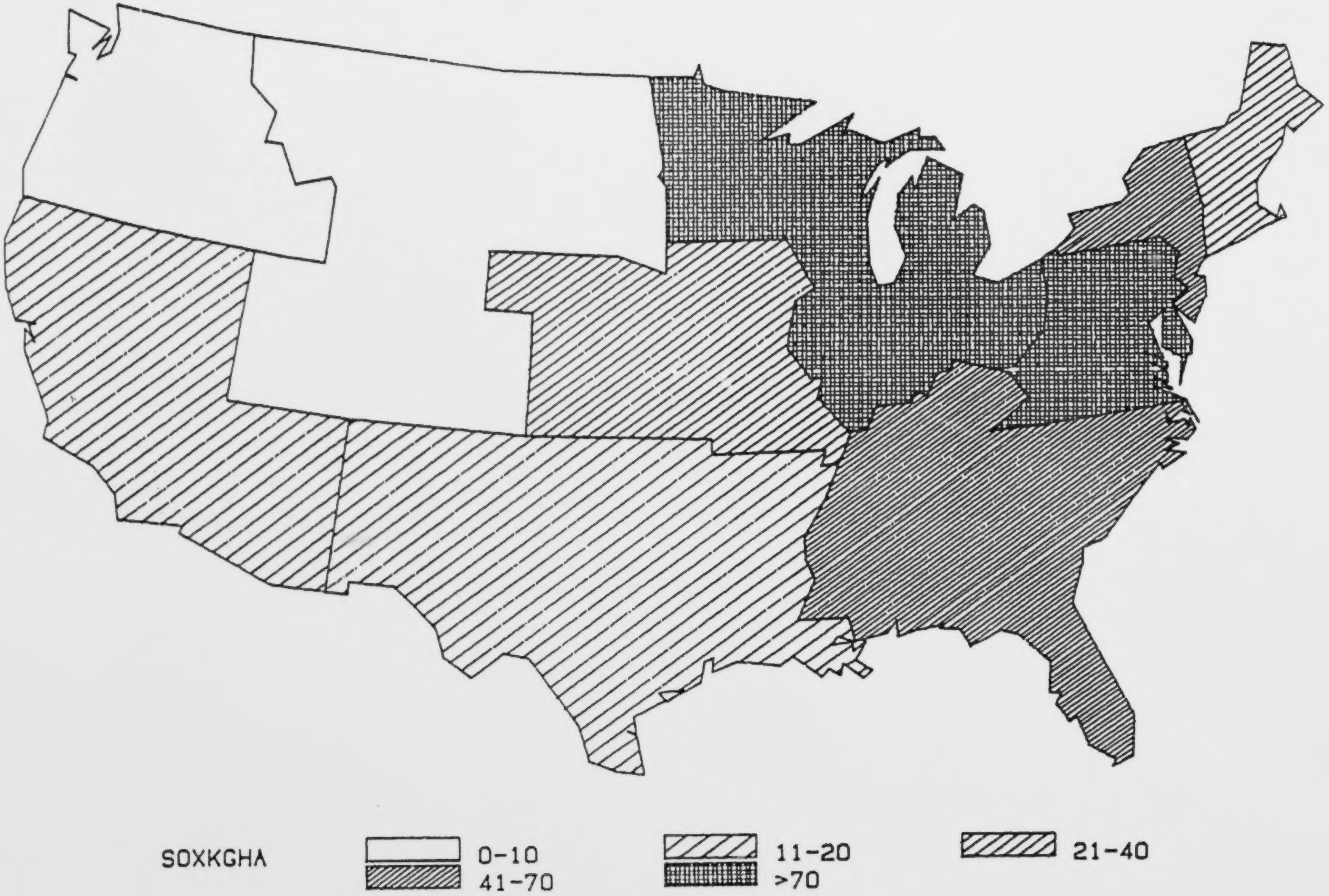

SOXKGHA
0-10
41-70
11-20
>70
21-40

Figure 18. SOx Regional Average Emission Density (kg/ha).

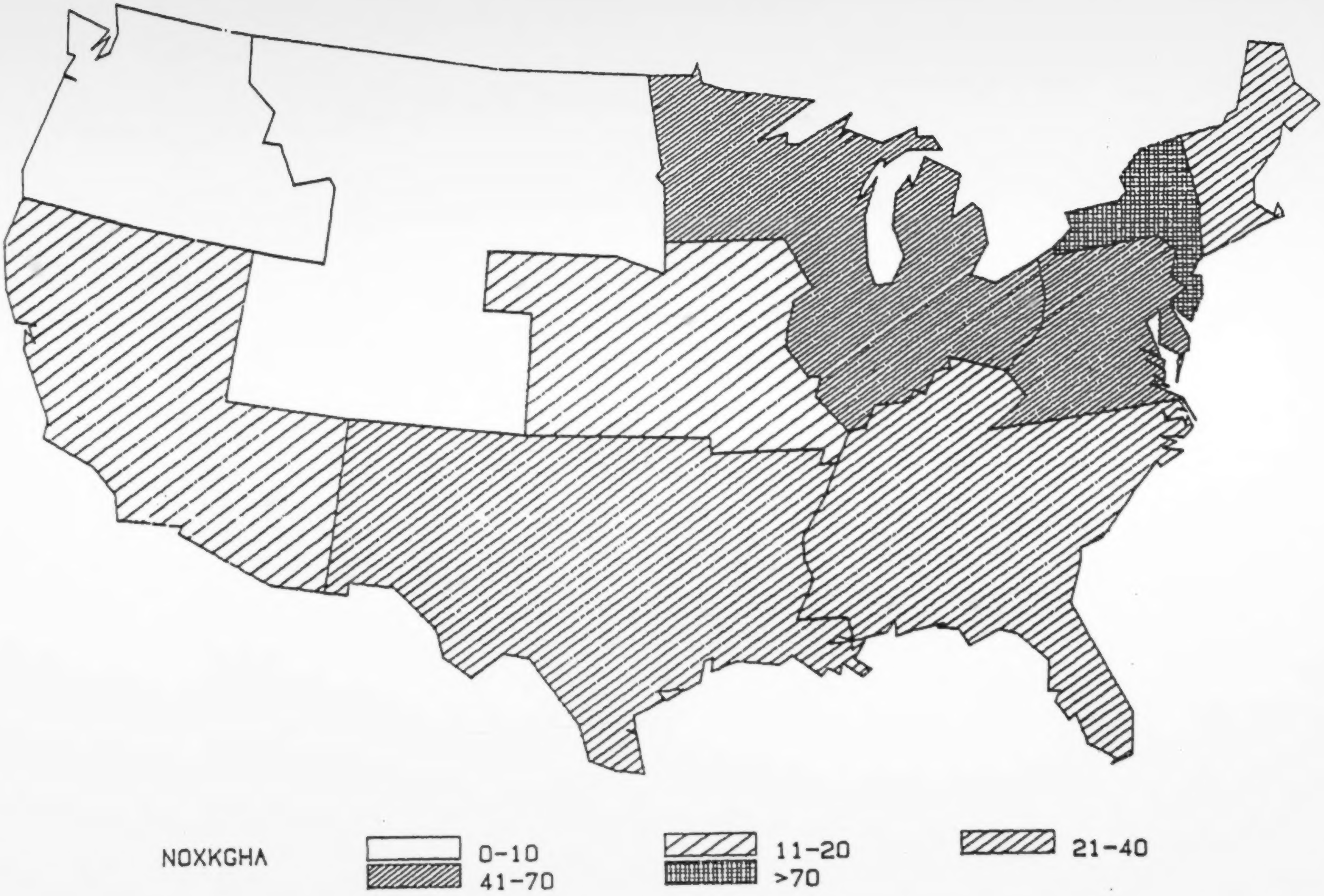

NOXKGHA
0-10
41-70
11-20
>70
21-40

Figure 19. NOx Regional Average Emission Density (kg/ha).

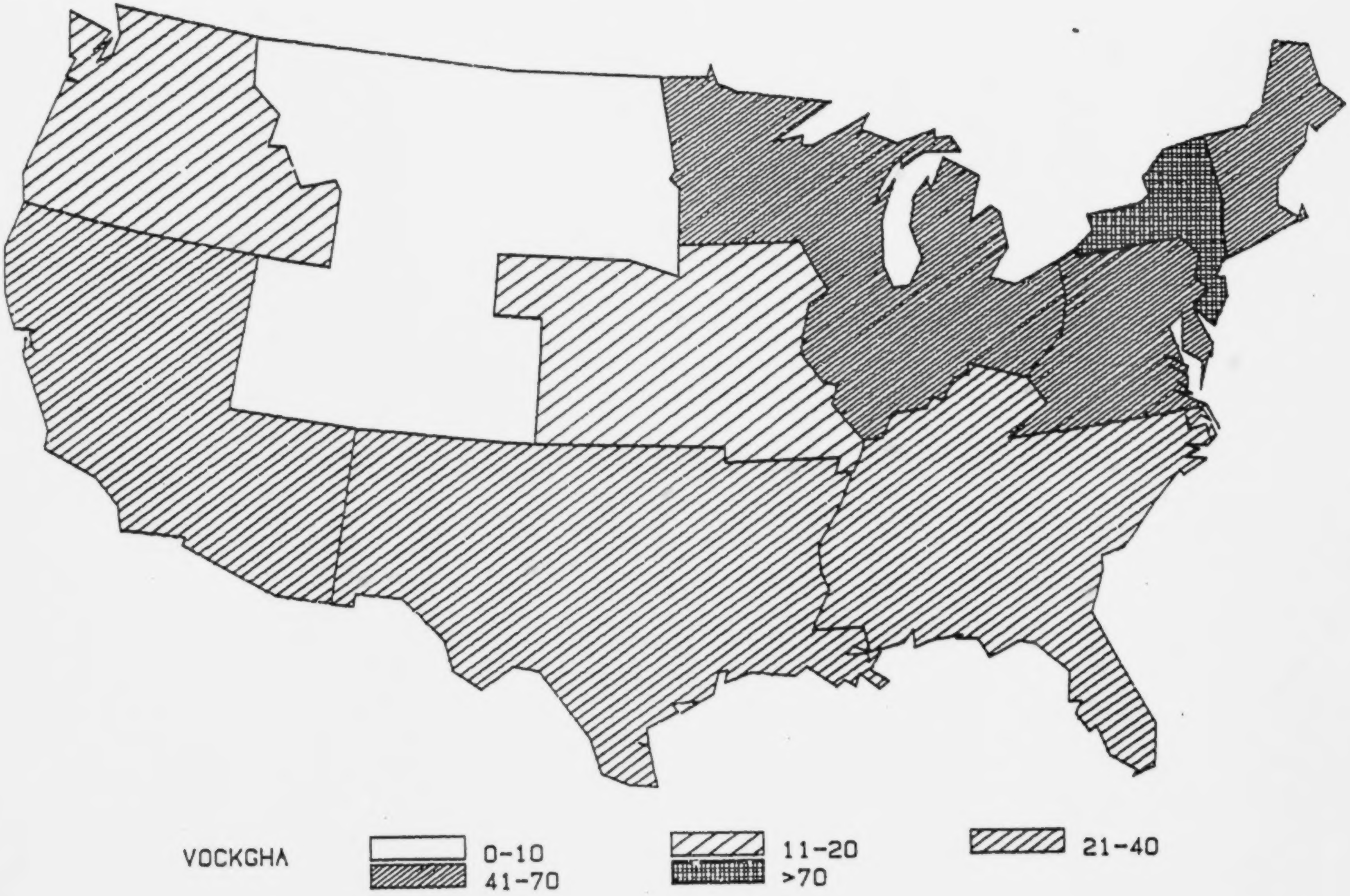

VOCKGHA
0-10
41-70
11-20
>70
21-40

Figure 20. VOC Regional Average Emission Density (kg/ha).

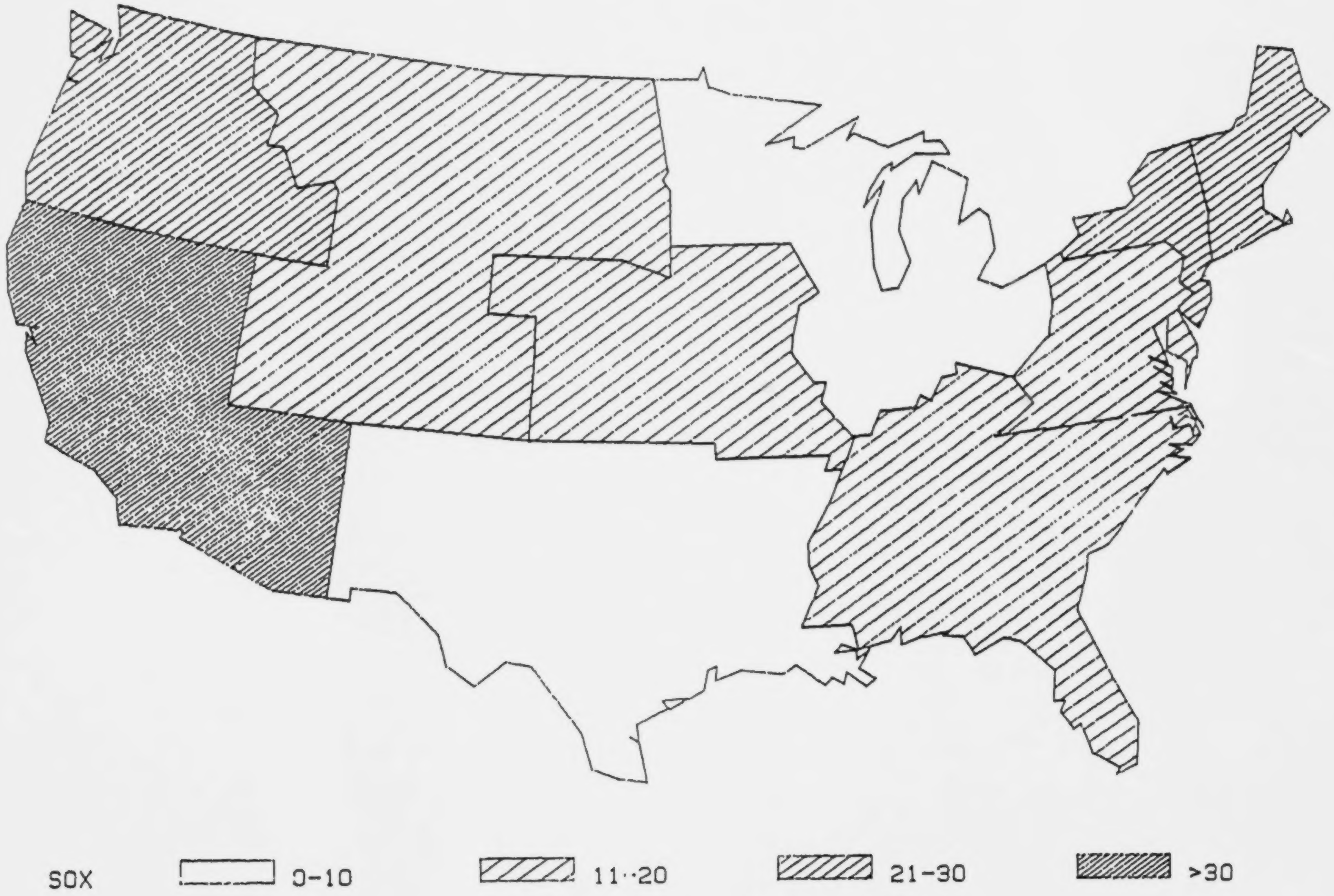

SOX
0-10
11-20
21-30
>30

Figure 21. SOx Regional Average Emission Density Variation (%).

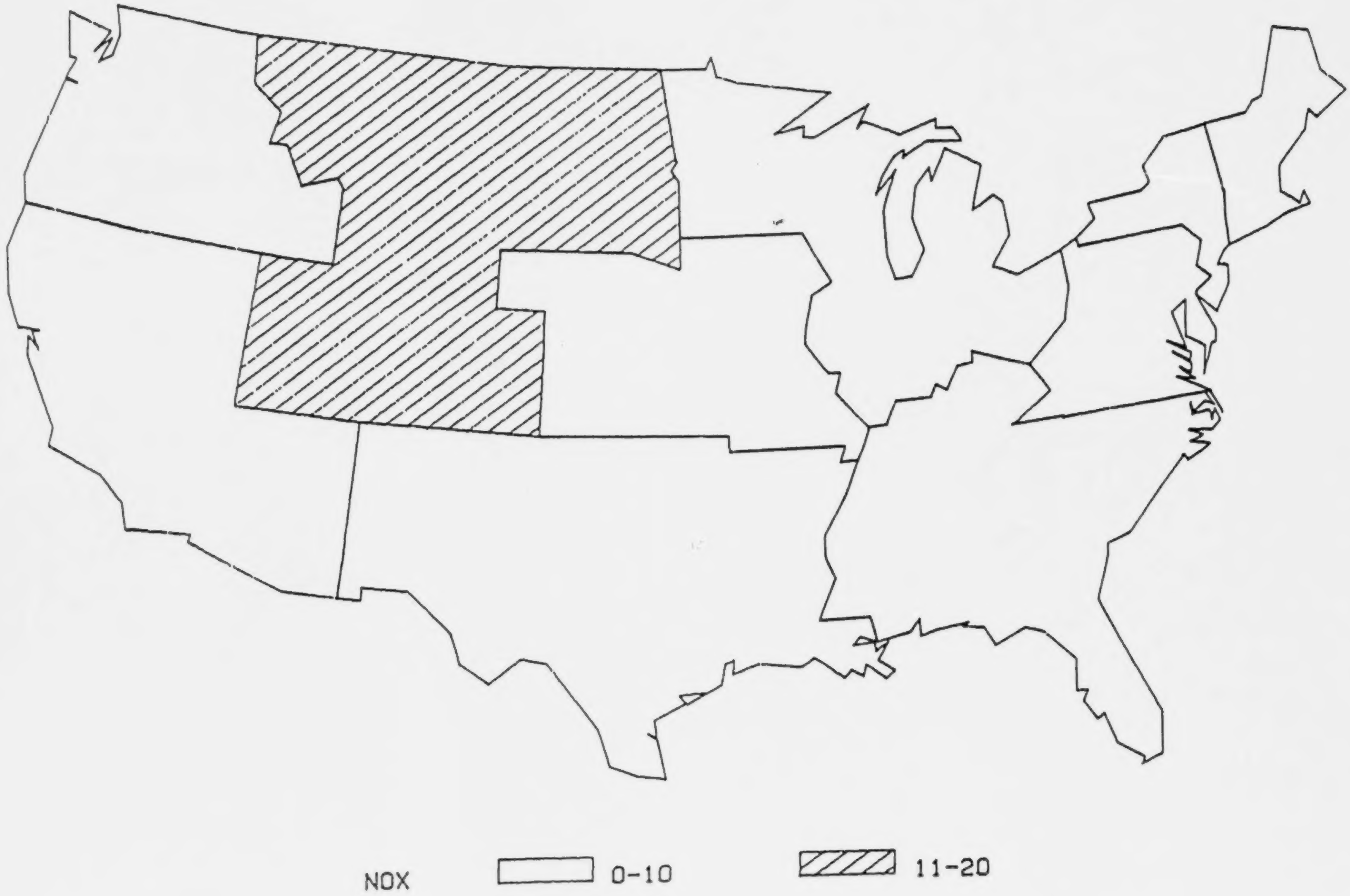

NOX
0-10
11-20

Figure 22. NOx Regional Average Emission Density Variation (%).

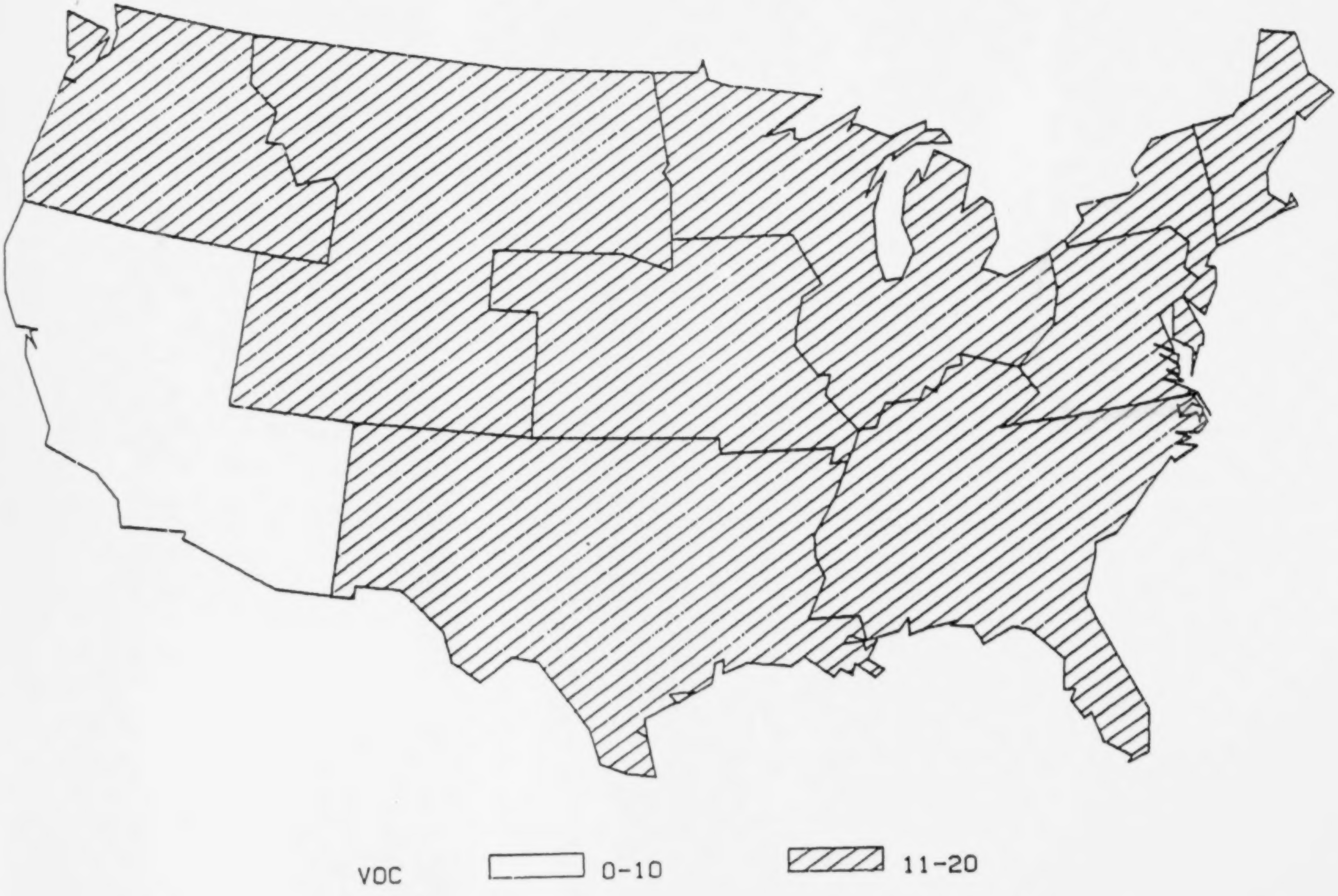

VOC
0-10
11-20

Figure 23. VOC Regional Average Emission Density Variation (%).

reflecting fluctuations in copper smelter emissions. Smelter emissions also had a noticeable effect on the results for Region 10. The relatively high variation in Region 3 was due to fuel combustion, both utility and non utility.

For NO_x, the highest variation was in Region 8, caused primarily by the large increase in electric utility emissions superimposed on a relatively small base of emissions from other activities.

For VOC, variations were small, averaging about 15 percent, and may be attributed mostly to changes in emissions from the surface coating industry.

MAJOR SOURCES

In general, large sources emit pollutants at a higher elevation, resulting in somewhat different patterns of atmospheric dispersion compared with sources emitting near ground level (transportation) or at relatively low levels (industrial boilers).

Analysis of large source effects requires the availability of detailed plant-specific emission inventories. The 1980 NAPAP Emission Inventory was used in this study.

Figures 24 through 26 show the locations of the top 25 SO_x, NO_x, and VOC emitters, respectively. These plants account for 23 percent of total SO_x emissions, 7 percent of total NO_x emissions, and 2 percent of total VOC emissions. The lower percentage for NO_x and VOC is due to the large share of these emissions attributed to transportation and other sources which, individually, are very small emitters. Among the top 25 SO_x emitters, one is a copper smelter and the rest are utility plants. For NO_x, 21 of the 25 highest emitters are utility plants and the remainder are industrial plants. For VOC, a variety of industrial sources are included in the top emitter list including a number of chemical plants and petroleum refineries.

The relative distribution of the top 100 plants versus total emissions by region are shown in Figures 27 through 29 for SO_x, NO_x, and VOC, respectively. For SO_x, the top 100 plants accounted for 49 percent of total emissions. For NO_x, the corresponding figure was 16 percent and for VOC, 5 percent.

For SO_x, the major emitting regions have an even larger share of major emitters (Figure 27). Regions 2, 6, and 8 are underrepresented by major emitters relative to their contribution to total emissions.

For NO_x, a similar situation occurs (Figure 28). Regions 4 and 5 have a particularly large share of major emitters while Regions 1, 6, and 9 are underrepresented.

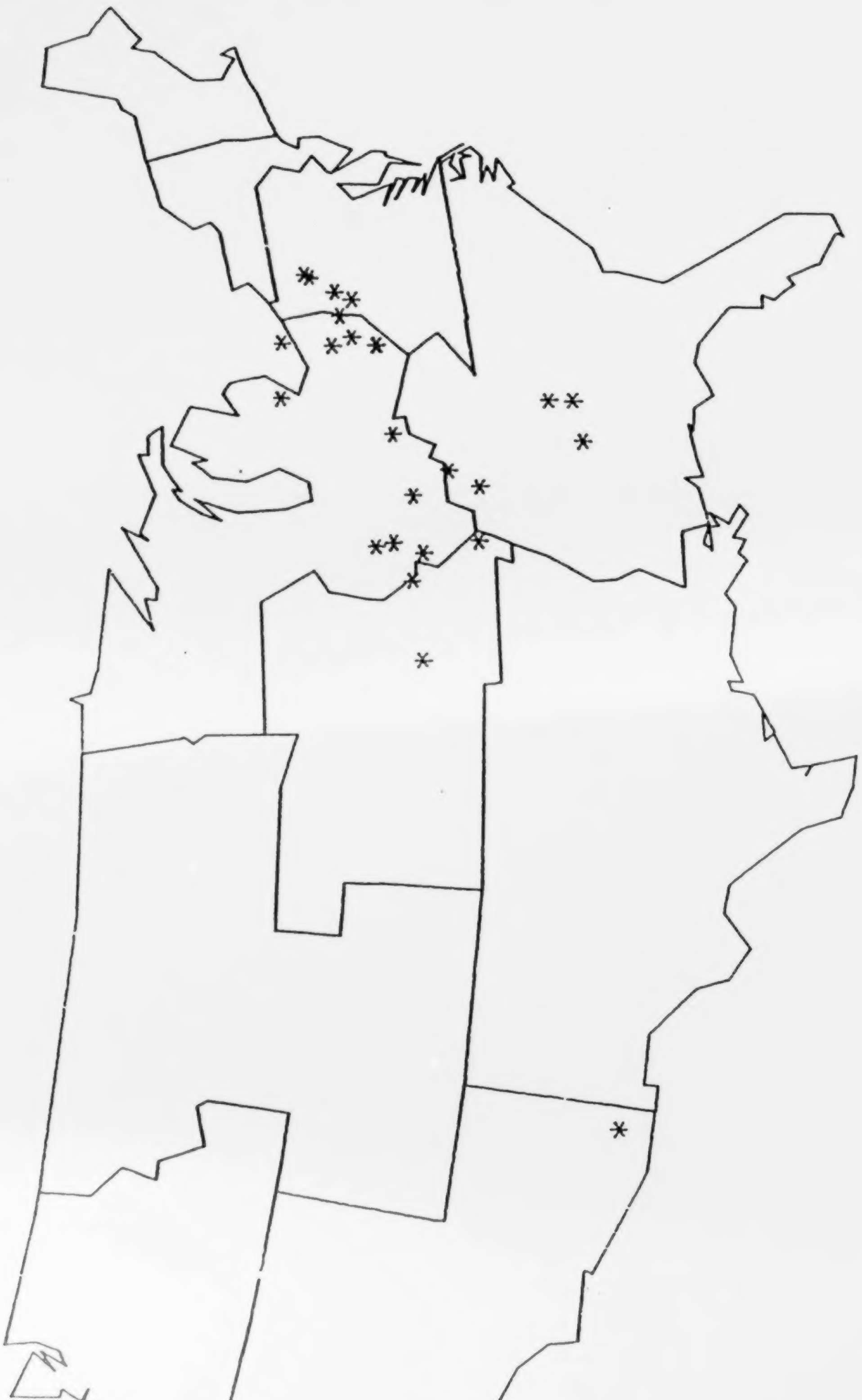


Figure 24. Top 25 U.S. SOx Emitters.

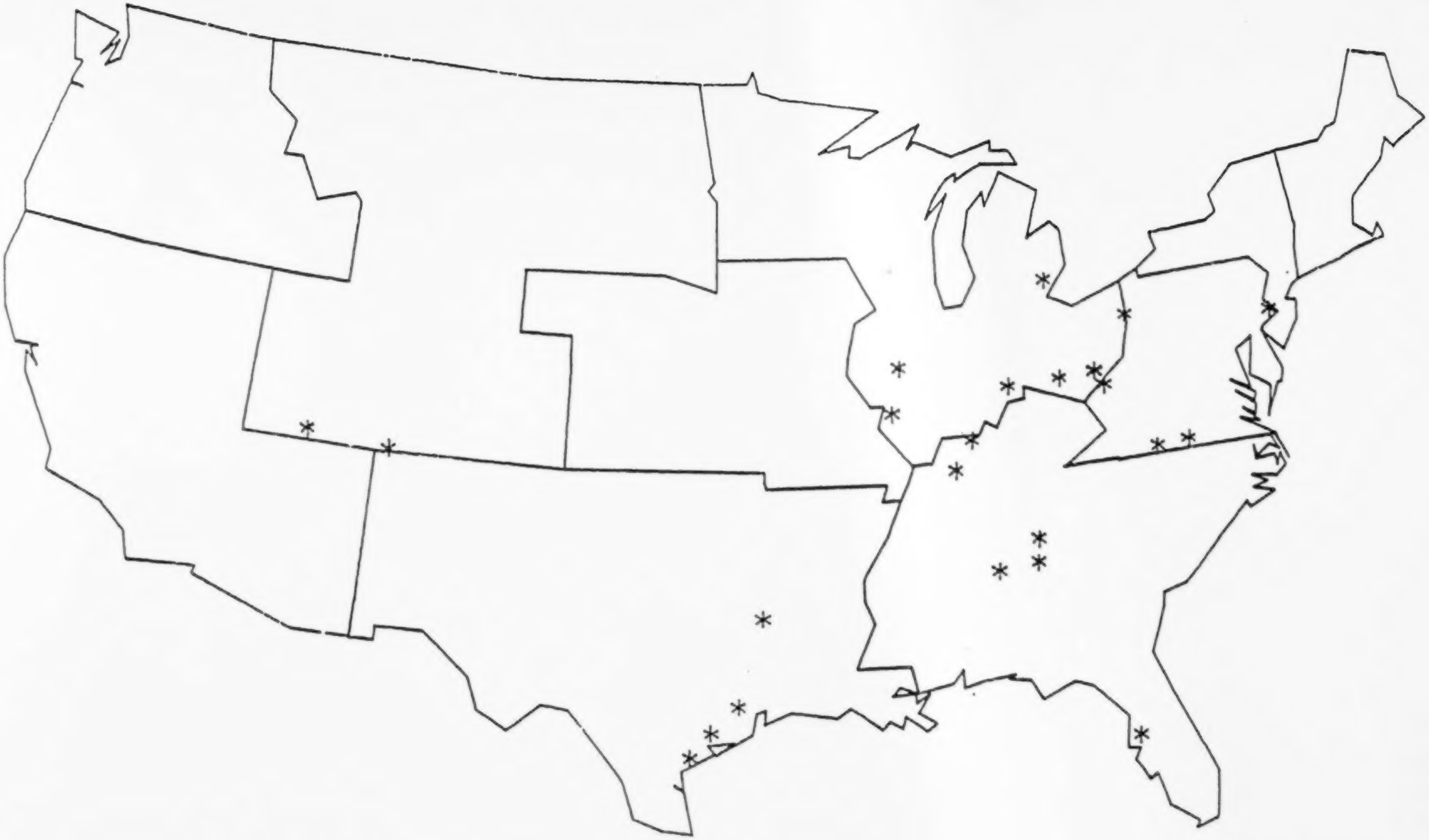


Figure 25. Top 25 U.S. NOx Emitters.

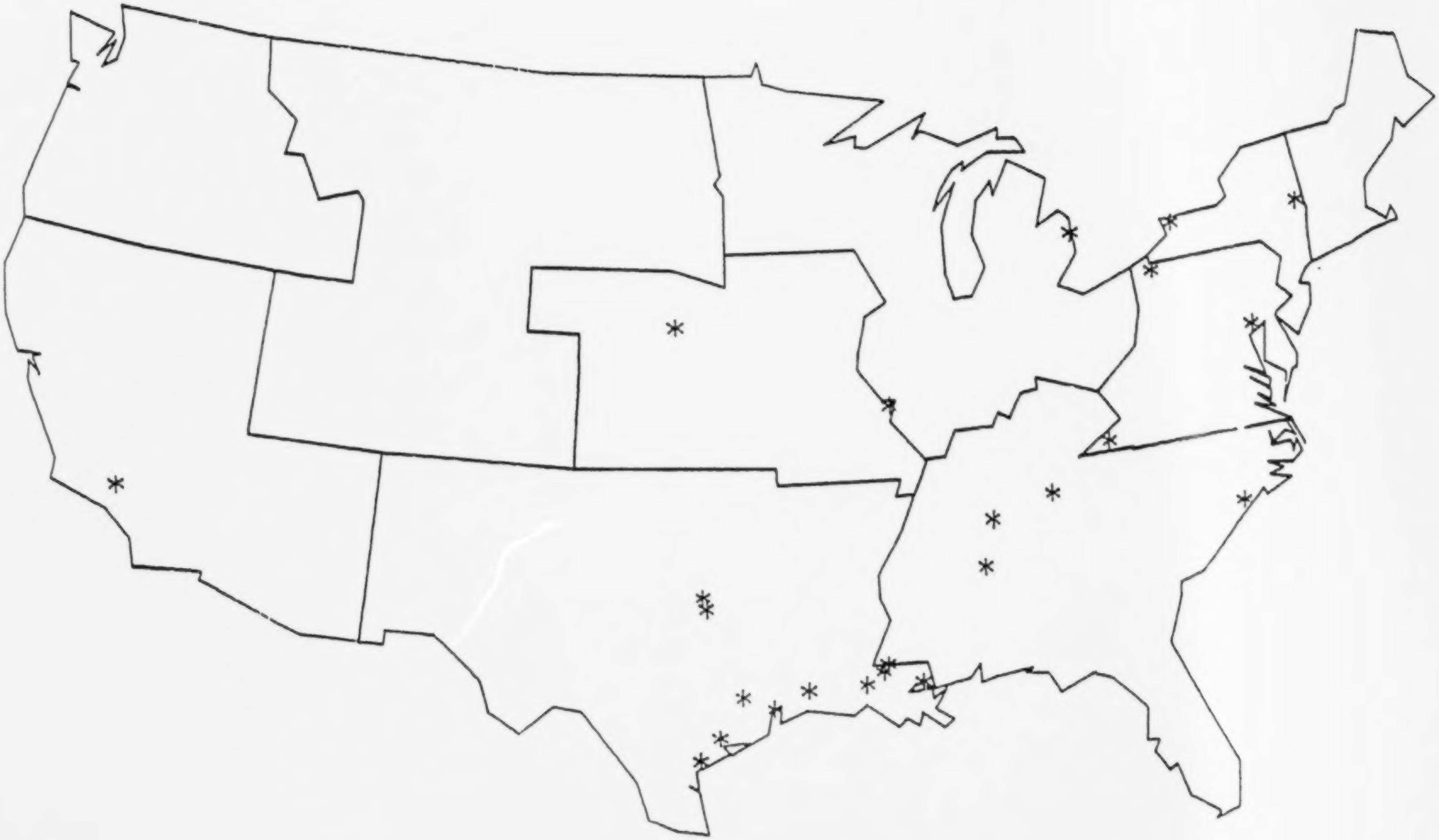


Figure 26. Top 25 U.S. VOC Emitters.

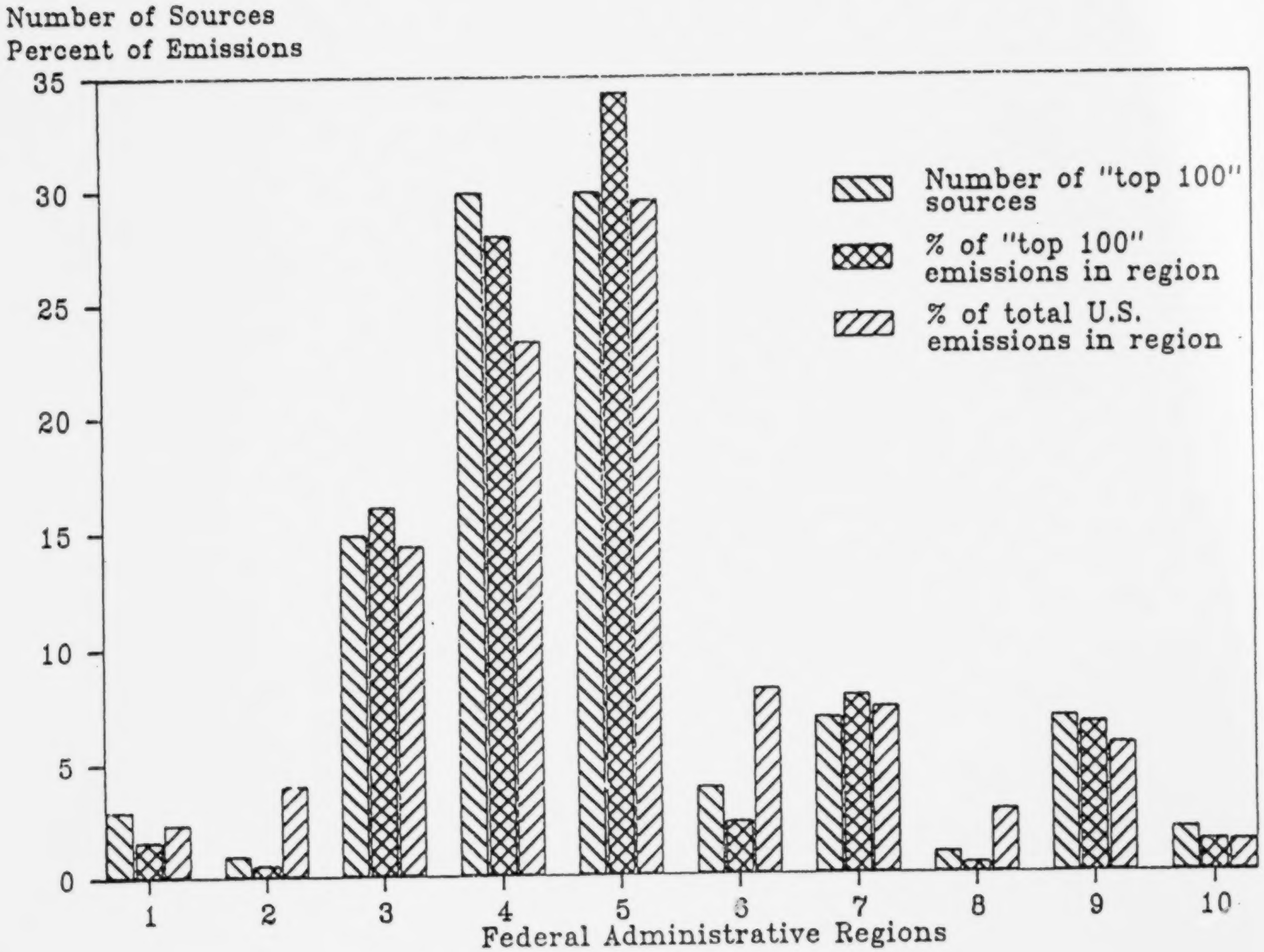


Figure 27. Characteristics of United States SOx emitterss by region (1980).

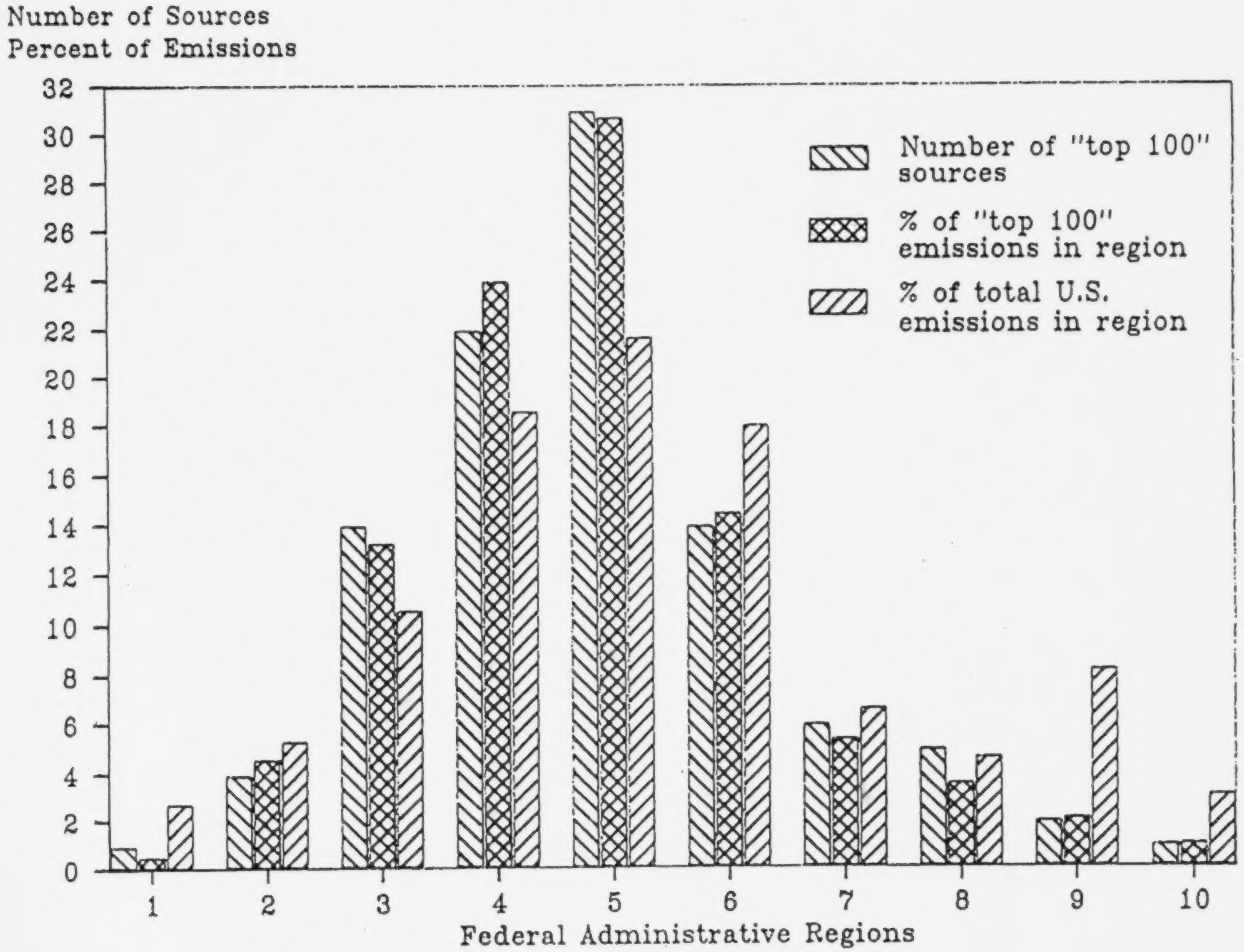


Figure 28. Characteristics of United States NOx emitters by region (1980).

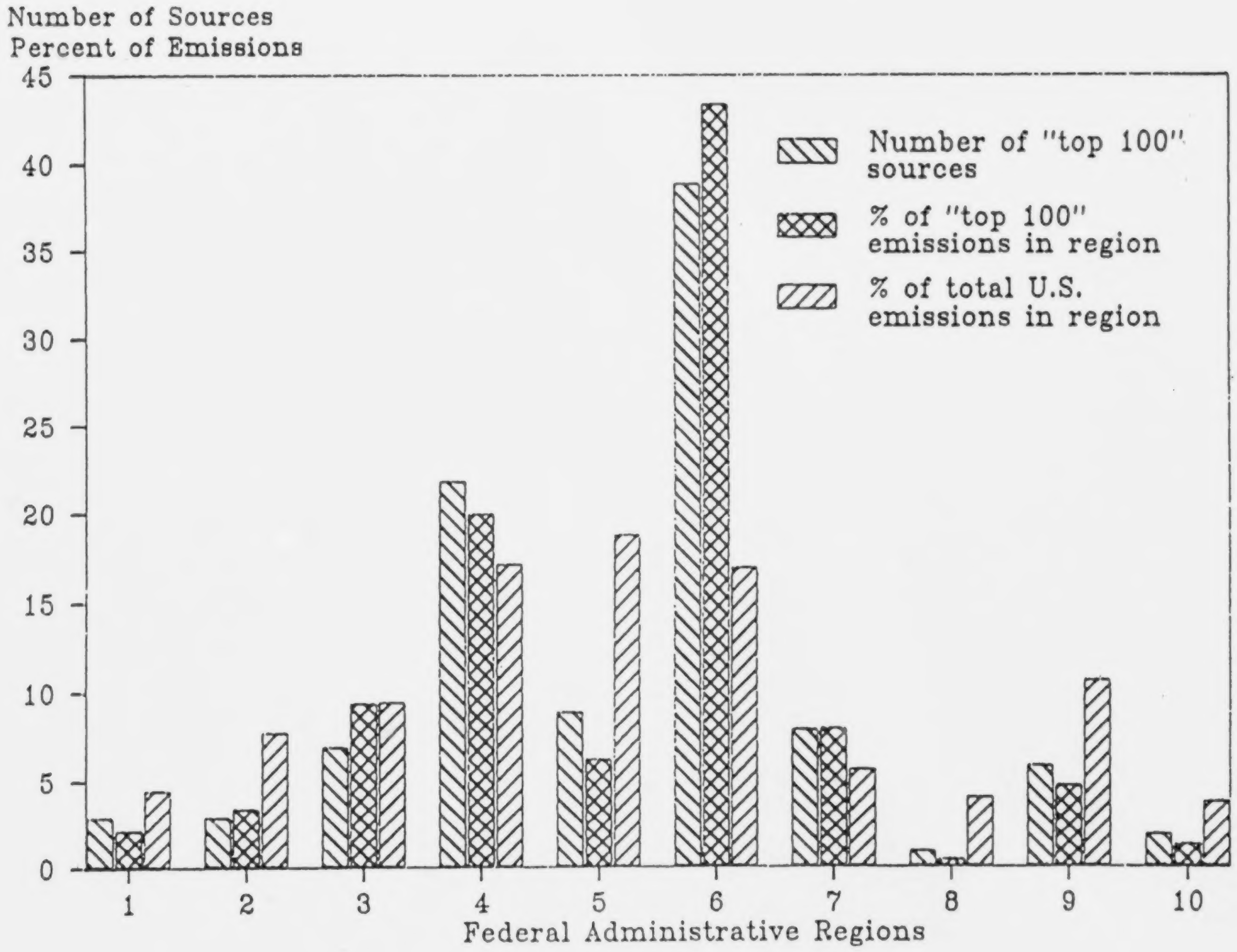


Figure 29. Characteristics of United States VOC emitters by region (1980).

For VOC, Region 6 has the largest share of major emitters followed next by Region 4 (Figure 29). The large share for Region 6 is due to chemical plants and oil refineries located in Louisiana and Texas.

SEASONAL EFFECTS

Atmospheric transport and chemistry as well as the deposition process itself are subject to considerable variation by season. As a result, efforts have been made to estimate seasonal and other more detailed temporal patterns of emissions. For the present study, a set of monthly emission estimates made by Argonne National Laboratory (Knudson, 1986) covering the period 1975 through 1984 was used. These data were converted to meteorological seasons (e.g., winter 1980 includes December 1979, January and February, 1980) in order to provide some insights into seasonal trends at the regional level. Although only a brief summary is presented here, the detailed data summaries resulting from this analysis will be made available to interested researchers.

The range of variation in seasonal share is relatively low with the variation higher for SO_x and highest for winter and summer. Year to year seasonal variations by region were relatively low, generally ± 1 percent for spring and fall and ± 2 percent for winter and summer.

The methods used to allocate annual to monthly emissions are subject to considerable uncertainty and, as a result, the somewhat surprising lack of strong seasonal variation may be due, at least in part, to artifacts of the analysis method used by Argonne. Despite this, however, these data are the best currently available and for that reason are included here.

SECTION 4

TRENDS BY SOURCE CATEGORY AND REGION

In this section, overall trends by broad source categories within regions are presented.

ELECTRIC UTILITIES

As indicated earlier, electric utilities are responsible for approximately two thirds of total national SO_x emissions and approximately one third of total national NO_x emissions. Since utilities are only a negligible source of VOCs, this section discusses only SO_x and NO_x.

By 1985, generation from electric utilities had increased by about 8 percent over 1980 levels. During the same period, emissions of SO_x had declined by a similar amount. NO_x emissions, on the other hand, increased by about 4 percent above 1980 levels. The reasons for these changes are discussed below.

Sulfur Oxides

Utility emissions of SO_x result from combustion of sulfur, which is present inherently to some extent in almost all fuels. Since the natural gas burned by utilities has only trace amounts of sulfur, emissions resulting from combustion of sulfur in gas are a negligible source of SO_x. Oil contains sulfur ranging from trace amounts to 4 to 5 percent for residual oil grades, which are those components left after lighter, more valuable products such as gasoline and light oils are refined from crude oil and removed from the processing stream. Reduced consumption of oil by utilities, however, combined with the use of desulfurized residual oil at a number of plants has reduced the share of oil-related utility SO_x to under 10 percent. Thus, nationwide, over 90 percent of utility SO_x emissions are related to coal combustion. In fact, only Region 1 had more utility SO_x emissions from oil than coal throughout the study period. Even in this region, the gap between oil and coal emissions has closed.

Coal use by utilities was about 22 percent higher in 1985 than in 1980, while coal-fired generation had increased correspondingly by about 21 percent. Despite this, coal-fired SO_x emissions declined by about 4 percent over this time period. These declines in emissions, despite increases in potential emissions-producing activity, were due to two factors: use of lower sulfur coals by utilities, and increased use of flue gas desulfurization hardware systems (FGD or scrubbers) to reduce emissions from burning coal. Use of lower sulfur coal reduced emissions by about 2.4 million metric tons while increased FGD usage resulted in another reduction of 1.4 million metric tons.

Figure 30 shows selected regional SO_x emissions. The average

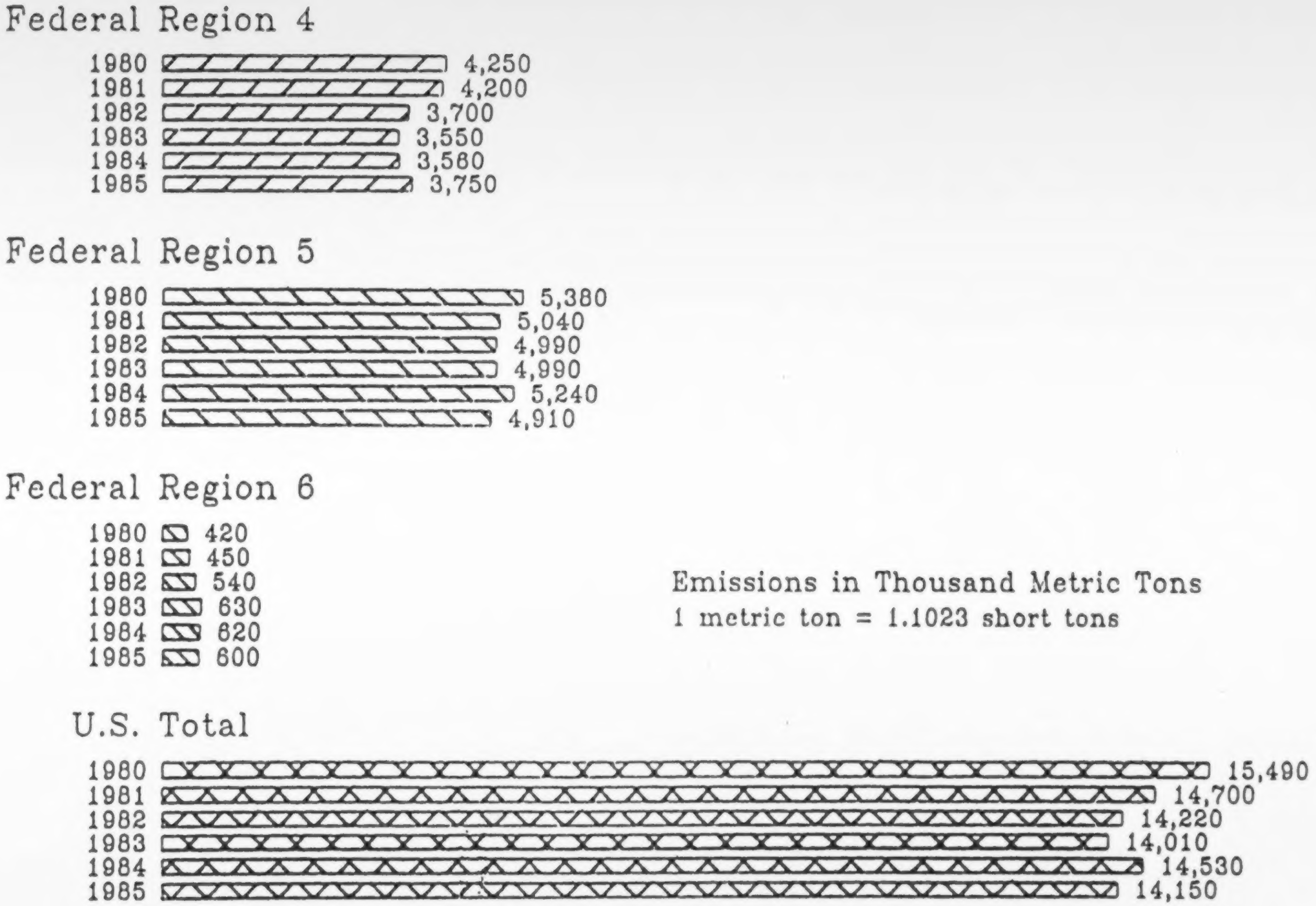


Figure 30. United States utility SOx emission trends by region (1980–1985).

percentage of sulfur in coal consumed by utilities declined in all of the major emitting regions, resulting in reduced emissions. More subbituminous and lignite coals were consumed; these coals inherently emit less of the sulfur they contain to the atmosphere. Increased low sulfur coal usage results from a combination of Figure 30 factors including (1) growth in electrical demand in areas having ready access to low sulfur coals, (2) increased market penetration of low sulfur coals, and (3) environmental regulations. In the future, coal market forces could reverse the current tendency to use low sulfur coal.

Plants whose emissions are regulated by the 1971 Federal New Source Performance Standards (NSPS) are required to use either low sulfur coal or FGD systems. Generally, these newer plants emit less than older facilities, which need only comply with emissions regulations designed to achieve National Ambient Air Quality Standards (NAAQS). However, the addition of new lower-emitting units, over time, will have the effect of reducing overall emissions only if older, higher-emitting units are retired. Increases in utilization of older, less well controlled plants, coupled with the use of higher sulfur coals, may result in higher overall emissions until the older plants retire. Retirement of a significant share of older plants, however, may not occur until far into the future.

The share of total SO_x emissions due to utility activities is consistently greater than one-third in all but Regions 6, 9, and 10. In Region 6, however, utility emissions have increased as new coal-fired utility units have come on-line supplementing and replacing gas-fired units.

Both Regions 6 and 8 have experienced higher than average growth in electric generation as well as increases in share of generation attributed to coal-fired units. Despite these increases, however, these regions together accounted for only about 7 percent of total national utility SO_x emissions.

NITROGEN OXIDES

While SO_x emissions result totally from combustion of sulfur in fuel, NO_x emissions are formed by both fuel-bound nitrogen and conversion of nitrogen already present in the atmosphere as N_2 into nitrogen oxide (NO) which is then further converted to NO_2. As a result, the focus of technology development on the control of NO_x has been on details of the combustion process such as the temperature at which combustion occurs and the amount of excess air (which can contribute more nitrogen and oxygen to react to form NO_x). Treatment of the flue gas to remove nitrogen (as FGD systems do for sulfur) has, to date, not been employed in the United States on a commercial scale and is not expected to be for a number of years.

In contrast to the case for SO_x, natural gas is a notable source of utility NO_x emissions, accounting for over 10 percent in each of the six years analyzed. Oil accounted for about 7 percent of NO_x emissions in 1980 but only 3 percent in 1985. This reduction results from continued declines in oil use by the electric utility industry beginning with the oil embargo of 1973-1974.

Trends in regional NO_x emissions were not strong over this time period in most regions. Figure 31 provides utility NO_x estimates for selected regions. While emissions increased by about 4 percent for the nation as a whole, four of the 10 regions experienced a decline in emissions while 6 experienced an increase. Notable declines of over 6 percent occurred in Regions 1 and 2. Significant increases of over 20 percent occurred in Regions 6 and 8. In Region 6, coal generation increased by over 80 percent above the 1980 level while the increase in Region 8 was almost 50 percent. Although much of the increased generation occurred in plants subject to NSPS requirements, the relative reduction achieved by NSPS for NO_x is much less than that for SO_x. Thus, increased activity (generation) translates directly into increases in emissions.

INDUSTRIAL ACTIVITIES

In this section, activities from selected key industrial subcategories are discussed.

Copper Smelters

Nationally, after increasing between 1980 and 1981, yearly SO_x emissions from copper smelters have declined significantly since 1981. These declines have been due primarily to reductions in smelter operation during the period. The vast majority of U.S. smelter emissions are associated with copper production, and the focus of the discussion in this section is on this segment of primary metals production.

The demand for copper is closely tied to business activity, especially building and construction, electronics, industrial machinery, and transportation (Standard & Poor, 1986b). The domestic share of the world market is affected by production costs, currency valuation, and foreign competition. During the 1980 to 1985 period, Third World copper production was at an all-time high, which led American companies to curtail output. In 1982, the domestic recovery drove demand high enough to decrease excess inventories, resulting in stabilized domestic production.

Domestic smelters are located in only a few states (primarily in Regions 6 and 9, and to a lesser extent, in Regions 5, 8, and 10), and the exogenous factors influencing demand for domestic copper do not affect the various regions differently in any significant manner.

Figure 32 reports smelter emissions for the nation and for

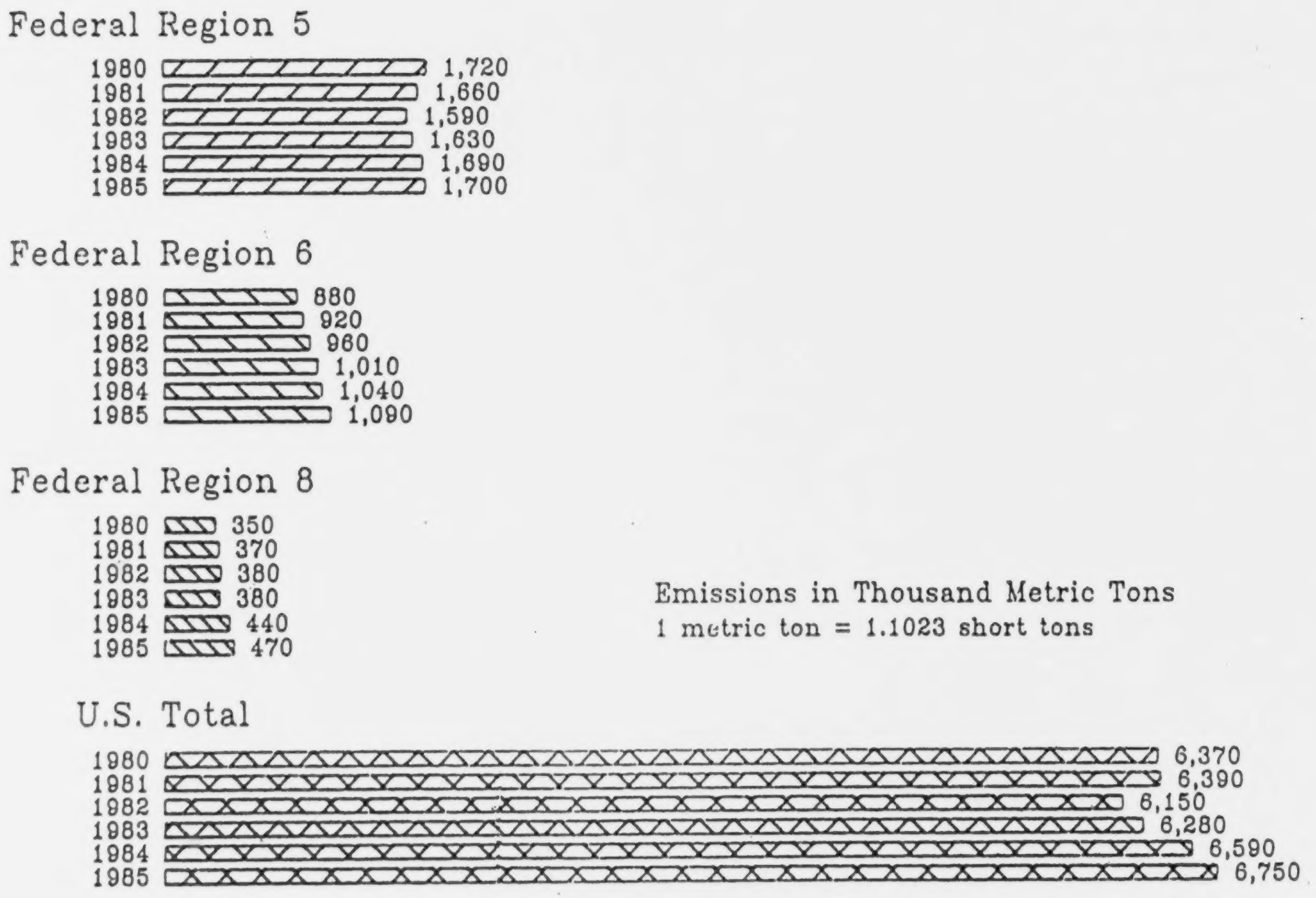


Figure 31. United States utility NOx emission trends by region (1980–1985).

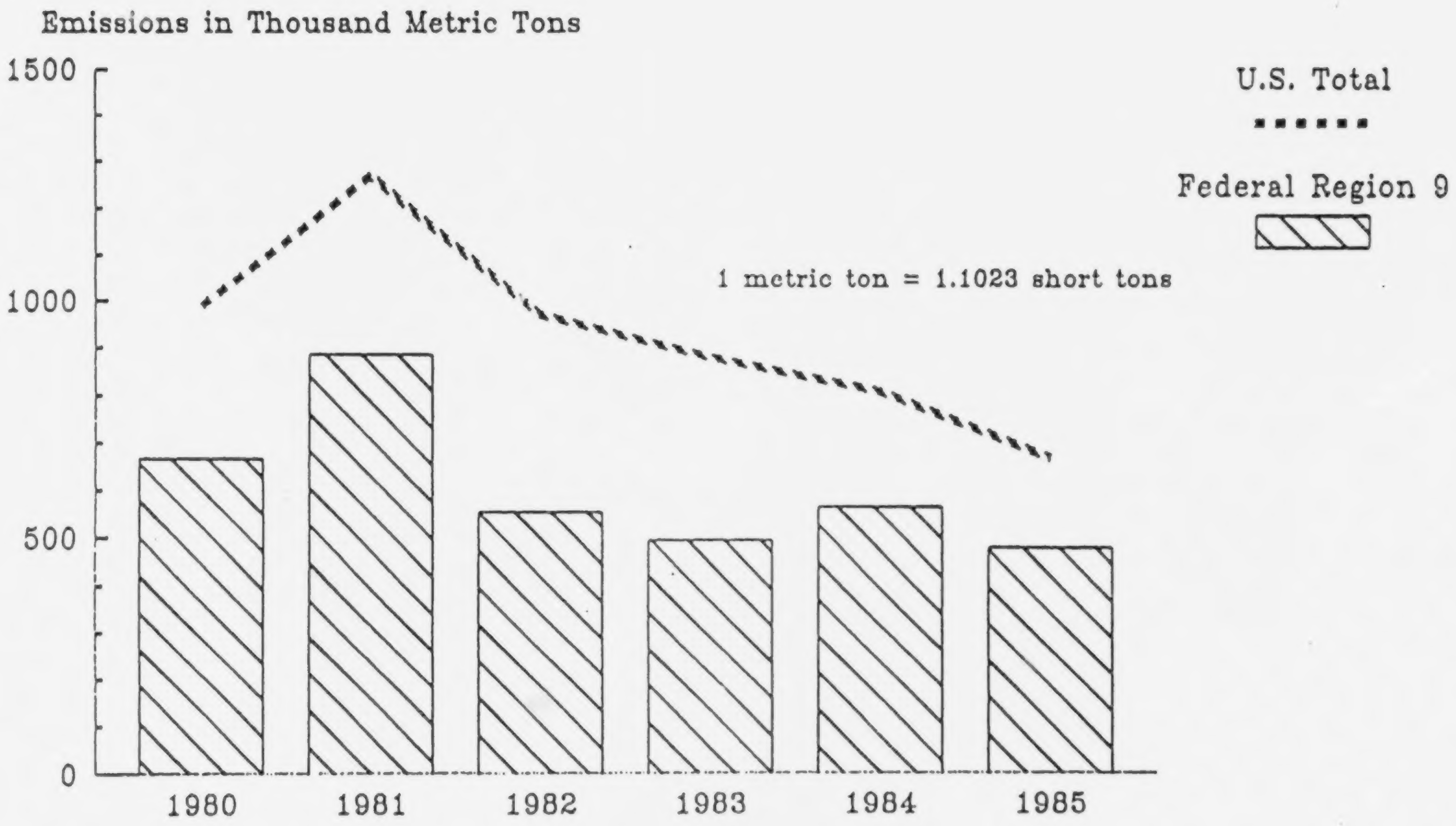


Figure 32. United States smelter SOx emission trends by region (1980–1985).

Region 9, the predominant source of smelter emissions. The following points summarize smelter operations and ensuing SO_x emissions during the 1980 to 1985 period:

- From 1980 to 1981, U.S. smelter production and domestic SO_x emissions both increased about 30 percent. The general increase in SO_x emissions was due to the increase in smelter operation over the previous year, evidently a response to (1) a strike that occurred in 1980 and (2) record high copper prices.

- In 1982, both SO_x emissions and smelter production fell by about 25 percent nationally. Regionally, there was great variation in SO_x emission trends: in Region 6, SO_x emissions increased by 16 percent over 1981 levels, while Region 9 showed a 37 percent decrease. The decline in smelter operations was due to curtailment of mine operations, in response to the increased inventories of refined copper built up during the previous years of increased production. Regional divergences resulted from shifts in operations to the most efficient plants as copper prices continued to fall.

- 1983 brought a continued overall decline in SO_x emissions (9 percent) and smelter operations (3 percent). The combination of expenditures required to comply with environmental regulations, continued diminished mine production, and realignment of production contracts had an adverse effect on smelter operation (Jolly and Edelstein, 1984). As in 1982, regional differences in SO_x emission trends resulted from continued closing of inefficient smelters and temporary shutdowns of smelters to install pollution control equipment.

- Trends in smelter production and smelter emissions diverged after 1983 due to the installation of pollution control equipment. Although smelter production of copper increased by 15 percent in 1984, and by an additional 3 percent in 1985, SO_x emissions declined by 8 percent and 17 percent, respectively.

Petroleum Refineries

Petroleum refinery SO_x emissions at the national level declined 12 percent between 1980 and 1982 and then remained constant through 1985. The changes between 1980 and 1982 can be attributed both to reductions in the amounts of crude oil processed by refineries and in the number of operating plants. Refinery crude inputs declined by 13 percent between 1980 and 1982 and have remained relatively constant since that time, while over 100 domestic refineries shut down from 1980 to 1985 (Standard & Poor, 1985).

All regions but Regions 2 and 7 followed the national trends.

Between 1980 and 1982 there was a 60 percent reduction in refinery SO_x emissions in Region 2 and a 40 percent reduction in SO_x emissions in Region 7. From 1982 to 1985 these regions, as well as all others, followed the national trends. The changes in Region 2 can be attributed to a 30 percent reduction in the number of operating refineries and a corresponding reduction in refinery capacity. In Region 7 there was a 25 percent reduction in the number of operating refineries and a corresponding reduction in refinery capacity.

Iron and Steel

Emissions of SO_x from the iron and steel industry have fallen 33 percent over the period from 1980 to 1985 (Figure 33). This overall decrease includes a decline of 44 percent to 1983 followed by a rise of 23 percent from 1983 to 1984 and a decline of 4 percent from 1984 to 1985. The greatest decrease from year to year (35 percent) occurred between 1981 and 1982. These increases and decreases in emissions roughly coincide with U.S. steel production, except for the 8 percent drop in emissions between 1982 to 1983, a period which saw a slight increase in production according to American Iron & Steel Institute figures (Standard and Poor, 1986a).

Three regions have accounted for significant volumes of SO_x emissions. Region 5 contributed approximately 50 percent of total national iron and steel emissions in 1985, up from 40 percent in 1980. Region 3 accounted for 34 percent of total emissions in both 1980 and 1985. Region 4 contributed only 14 percent of national iron and steel emissions in 1985, up slightly from its 11 percent share in 1980.

Region 5, the highest emitting region throughout the five years, exhibited a sharp decline in iron and steel SO_x emissions from 1981 to 1982 but slight increases for all other years. The overall decline in emissions from 1980 to 1985 was 18 percent for this region.

The second highest emitting region has been Region 3. Emissions declined sharply from 1981 to 1982, rose significantly over the next two years, then declined again from 1984 to 1985. The decline in the last year of 14 percent contrasts with the slight increases shown by the other two high emitting regions.

The third highest emitting region, Region 4, showed an overall 16 percent decline in iron and steel emissions. Emissions in this region fell sharply from 1980 to 1982 then rose steadily and appear to have tapered off in 1985.

TRANSPORTATION

As transportation sources contribute only a small fraction to national SO_x emissions, this discussion focuses on NO_x and VOC emission trends. Also, since the vast majority of emissions are

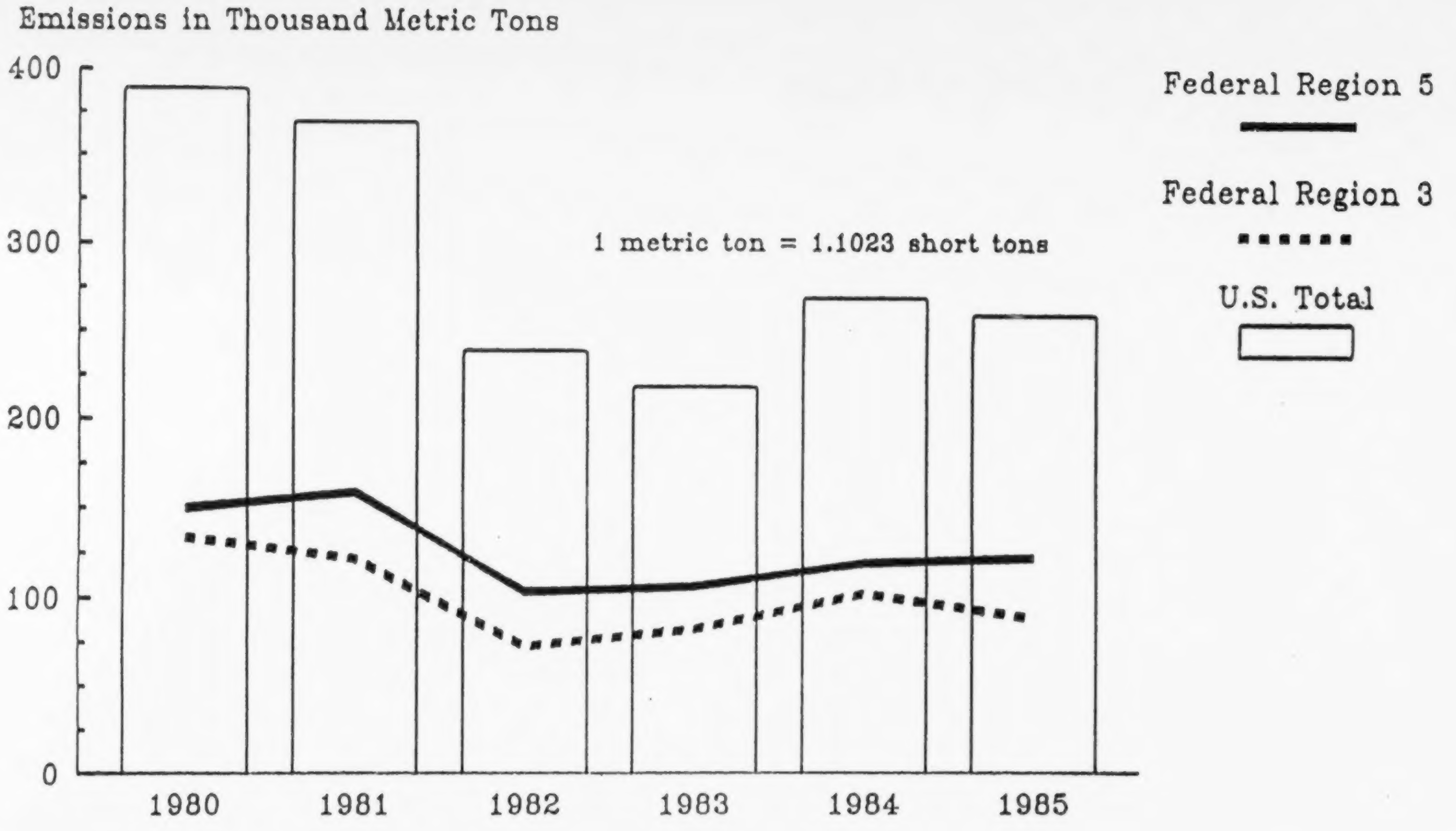


Figure 33. United States iron and steel SOx emission trends by region (1980–1985).

associated with highway vehicle use, the analysis of trends concentrated on this subcategory of transportation.

Trends in highway vehicle emissions are driven by three main factors: (1) the number of vehicle miles traveled (VMT) by vehicle type, (2) the fraction of travel by each model year of vehicle (the newer the vehicle, the more stringent the emission standard, so the higher the fraction of new vehicles in the fleet, the lower the per vehicle emission rate), and (3) the effectiveness of vehicle emission controls.

National NO_x emission trends show a decline from 1980 through 1982 or 1983 and an upward trend in 1984. VOC emissions decreased each year during the study period, although the decrease was not as pronounced in 1984 and 1985 as it was in the early 1980s (Figure 34). NO_x and VOC emission declines from highway vehicles in the early 1980s were anticipated as the 0.41 gram per mile light-duty vehicle hydrocarbon (HC) standard became effective with the 1980 model year, and the 1.0 gram per mile NO_x standard became effective with the 1981 model year. These standards achieve the goals of 90 percent reduction in HC and a 75 percent reduction in NO_x from precontrol levels for passenger cars.

While there was a reasonable expectation that the stringent light-duty vehicle emission standards would produce further downward trends in emissions, this reduction did not materialize. The most obvious factor affecting the emission trends is growth in VMT. VMT increases in the early 1980s were about 2 to 3 percent per year, but jumped to 4.1 percent between 1982 and 1983, and have remained above 3 percent through 1985 (U.S. DOT, 1986). In addition, the median age of passenger cars has increased from five years in 1970 to almost seven years in 1985 (MVMA, 1986), which means that the percentage of newer, well-controlled cars in the fleet is lower in 1985 than it would have been had the fleet turnover rate remained the same. The ranks of cars that are 16 years old or older almost doubled from 1980 to 1985, from 3.4 percent to 6.7 percent.

Reliable statistics are not available to indicate the extent to which misfueling and tampering with vehicle emission controls affect emissions. However, it is known that a relatively minor degree of misfueling and tampering has a significant impact on vehicle emissions. Misfueling is likely to decrease in the future as leaded gasoline is phased out.

Another factor, which influences NO_x emissions more than VOC, is that light-duty truck VMT has grown more rapidly than passenger car VMT. This tends to increase NO_x emissions from highway vehicles, offsetting small reductions in passenger car NO_x emissions due to tightened controls. From 1980 to 1985, passenger car VMT increased 16 percent, while passenger car NO_x decreased by 5 percent. On the other hand, light-duty gas truck VMT increased 25 percent and medium-duty gas truck VMT increased

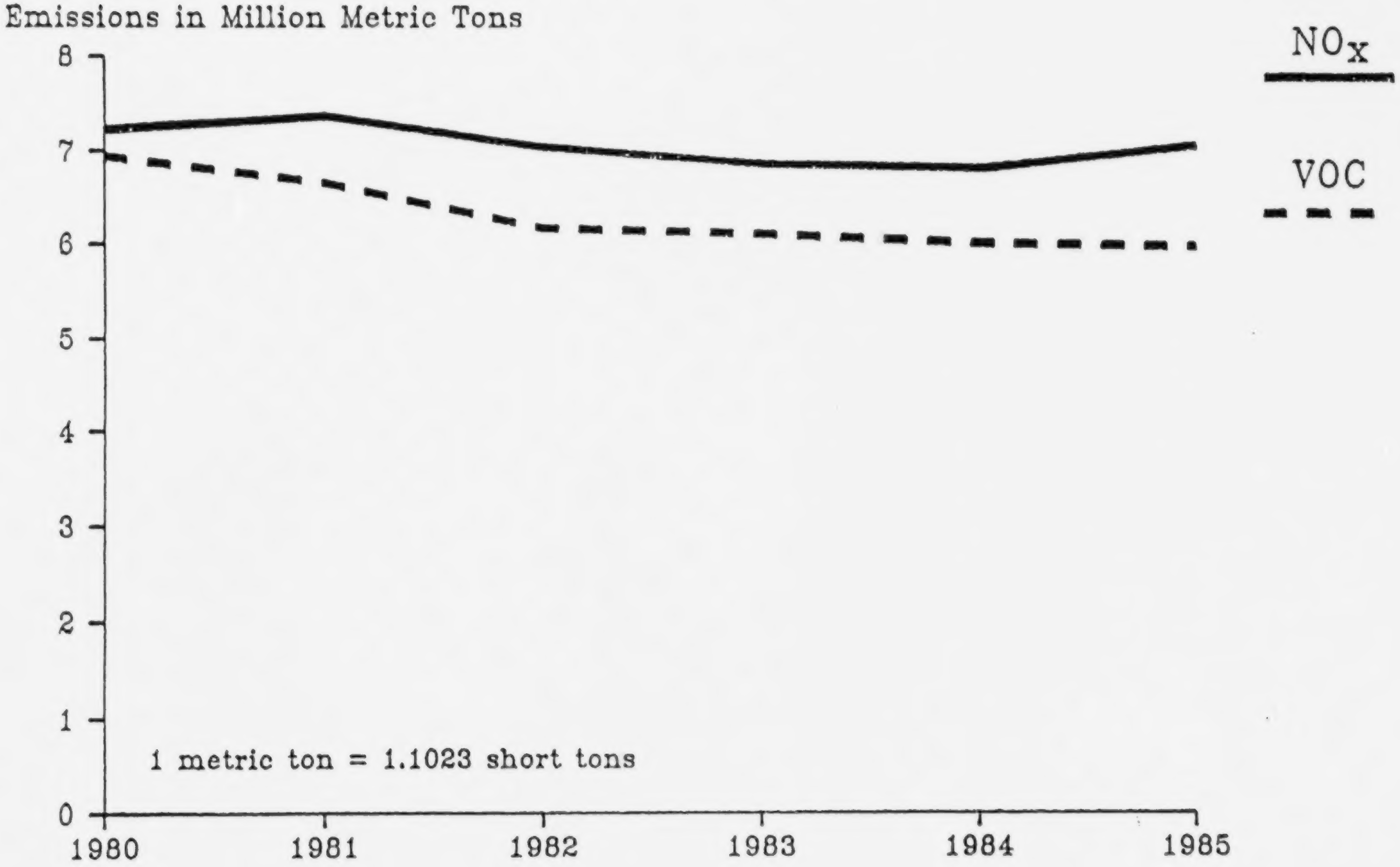


Figure 34. United States highway vehicle NOx and VOC emission trends region (1980–1985).

23 percent. NO_x emissions from light-duty gas truck and medium-duty gas truck VMT increased 25 percent and 19 percent, respectively. Light and medium-duty truck NO_x emission trends more closely resemble VMT trends because emission standards for these vehicles through 1985 have been less stringent than for passenger cars. Thus, in order to achieve future NO_x emission reductions, more stringent NO_x controls for trucks are needed.

In summary, the combination of higher-than-anticipated VMT increases, increased popularity of less well-controlled new vehicles, and lower vehicle turnover rates served to push highway vehicle NO_x emission rates in 1984 and 1985 above those observed in the early 1980s and made the downward trend in VOC emissions flatten out.

Highway vehicle NO_x emission trends at the regional level can be divided into two distinct groups: east and west. Eastern regions (Regions 1 through 5) show the same downward, then upward movement in emissions as seen in the national summaries. Western regional (6 through 10) highway vehicle emissions do not show any discernible trend during the study period as VMT increases seem to balance the emission reducing effects of more stringent emission standards. Figure 35 reports NO_x emissions for selected regions.

Downward trends in VOC emissions are seen in most regions, although this trend flattened out by 1984 or 1985 in many cases. The most pronounced downward trend in VOC emissions from highway vehicles is seen in Region 5. The only region that has a distinctly different trend in VOC emissions is Region 9, where increases of VMT push emissions up in 1984 and 1985 after declines in the early 1980s. Figure 36 reports VOC emissions for selected regions.

OTHER SOURCE CATEGORIES

The major source categories account for over 95 percent of total SO_x and NO_x emissions and are expected to continue to do so for the foreseeable future. However, for VOC, the other source categories account for about one-fourth of total emissions. This section focuses on those other source subcategories contributing to VOC emissions.

VOC emissions from residential wood combustion account for over 10 percent of total VOC emissions from all sources despite the fact that residential wood accounts for only a small share of the total home heating fuel market. This occurs because fireplaces and most wood stoves have low combustion efficiencies and substantial amounts of unburned or partially burned VOCs are emitted to the atmosphere. In fact, while residential wood combustion accounts for much less than 1 percent of total fuel heat value consumed, it accounts for about 90 percent of VOC from stationary source combustion. However, it should be noted that there is considerable uncertainty concerning both the quantities

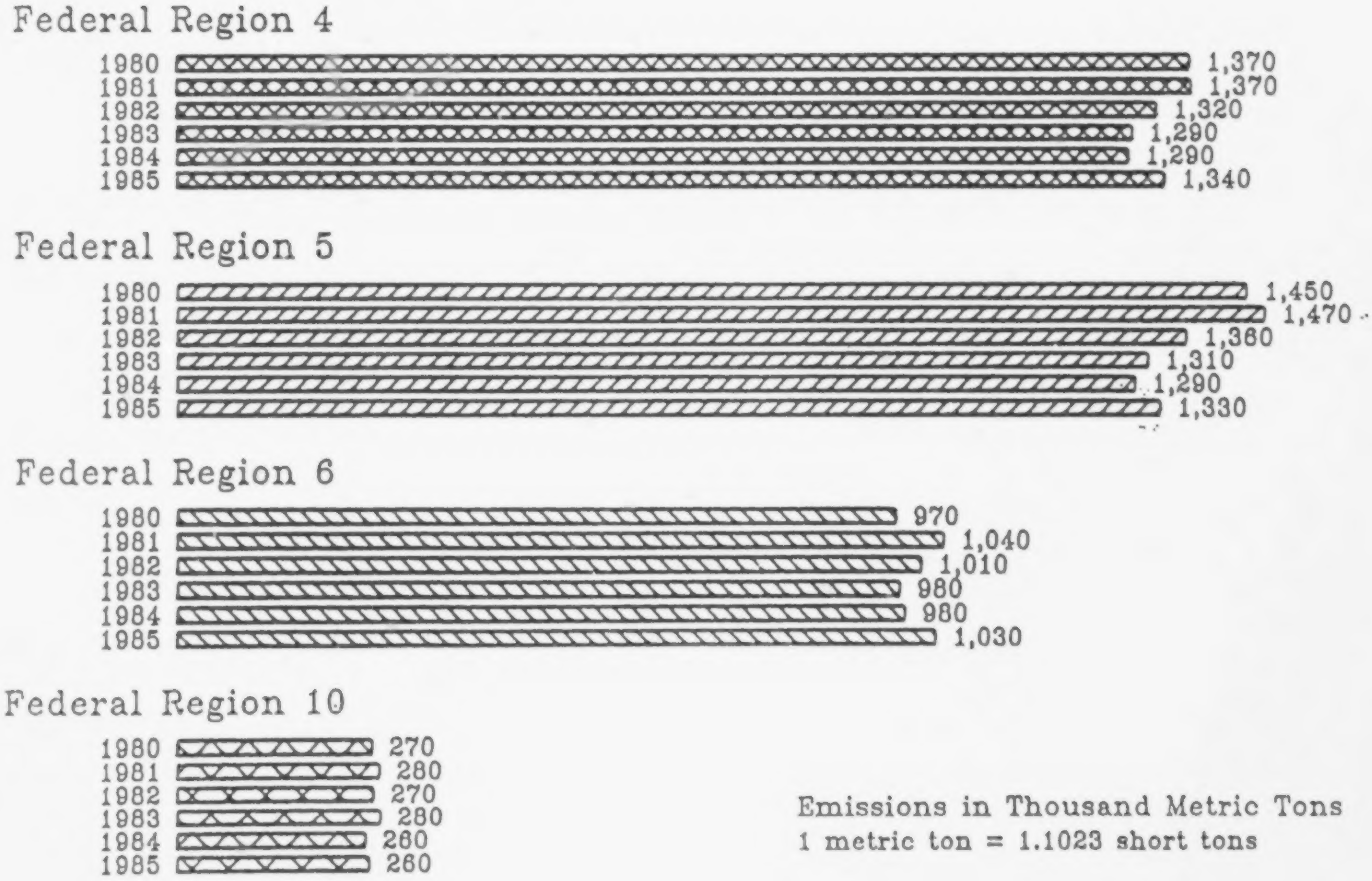


Figure 35. United States highway vehicle NOx emission trends region (1980–1985).

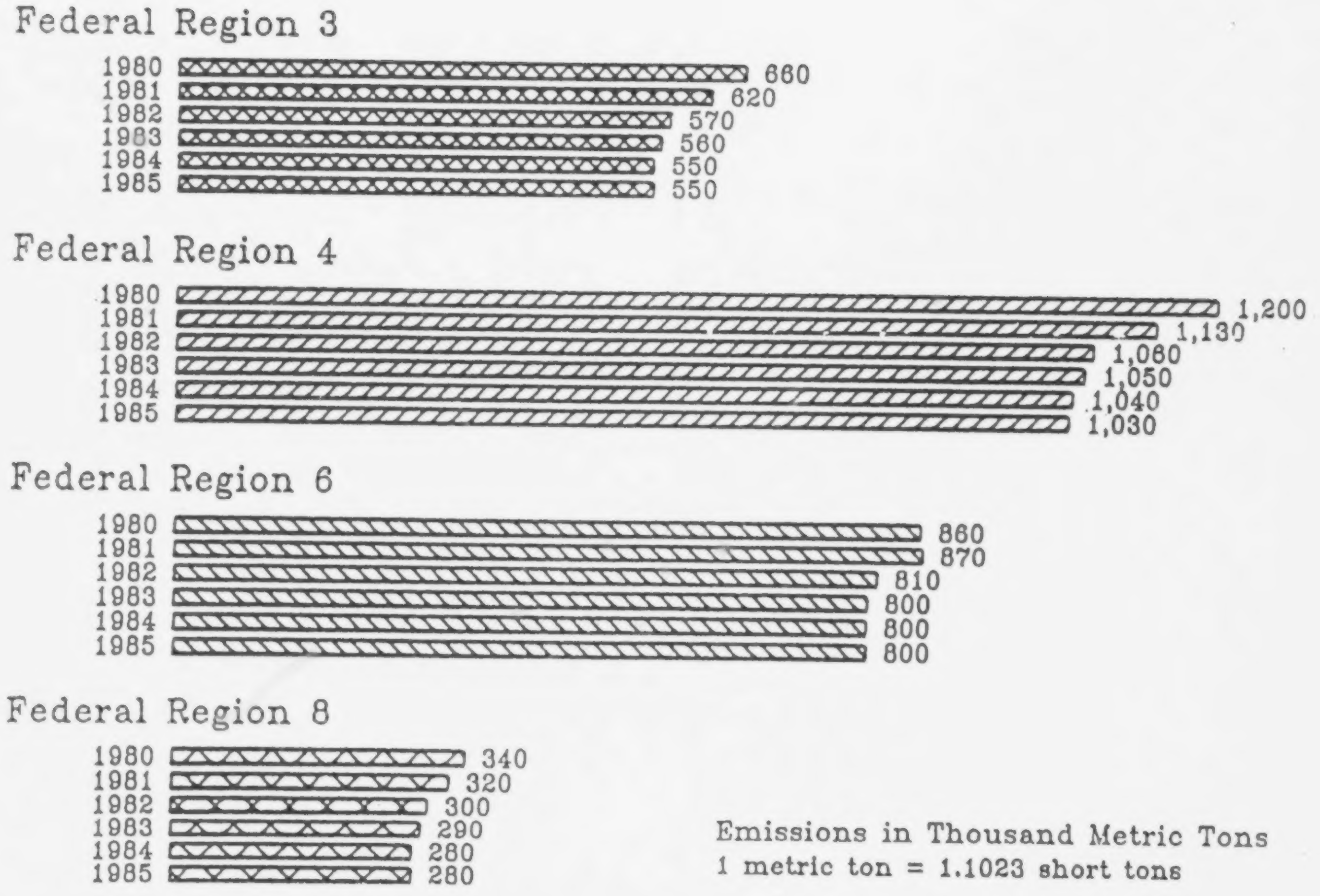


Figure 36. United States highway vehicle VOC emission trends by region (1980–1985)

of wood used in residences as well as the actual emissions associated with wood combustion.

VOC emissions from residential wood combustion have increased 25 percent since 1980 due to high prices for oil which made the use of wood comparatively economical. To date, substantial use of wood has been concentrated primarily in rural areas. Even in these areas, the number of wood burning units, the significance of their VOC (and carbon monoxide and particulate) emissions, along with the low height at which emissions are released have resulted in local restrictions and emission limits. These emission limits are expected to be of more significance in the future. Regions 3, 4, and 5 have the largest share, together accounting for about half of the total.

Other VOC source subcategories assigned to this category include forest and other fires and miscellaneous organic solvent usage. Again, there is considerable uncertainty associated with estimates of emissions from these categories.

EMISSION ESTIMATES BY STATE

United States emission estimates by state are presented in Table 1. This table shows 1980 SO_x, NO_x, and VOC estimates by state as reported in Version 5.0 of the 1980 NAPAP Emissions Inventory. The top five SO_x emitting states are Ohio, Indiana, Pennsylvania, Illinois, and Missouri. SO_x emissions in these states are primarily a product of coal combustion at utilities and major industrial sites. States with more than one million metric tons of NO_x emissions in 1980 include Texas, California, and Ohio. California also has more than 1 million tons of VOC emissions in 1980, as do Texas, Pennsylvania, and New York.

TABLE 1. ANNUAL U.S. EMISSIONS BY STATE -- 1980 NAPAP 5.0 EMISSION INVENTORY

Metric Tons/Year

STATE	SO_x	NO_x	VOC
Alabama	777,955	442,031	355,154
Arizona	765,735	239,401	230,513
Arkansas	79,040	191,546	202,427
California	471,553	1,254,422	2,010,889
Colorado	127,131	276,490	323,830
Connecticut	57,756	126,779	257,808
Delaware	113,097	56,487	69,948
Dist. of Colum.	13,903	22,999	39,992
Florida	1,000,619	646,105	751,666
Georgia	816,539	535,829	461,180
Idaho	50,993	83,347	201,445
Illinois	1,328,590	882,679	896,938
Indiana	1,787,943	713,812	510,494
Iowa	303,252	277,375	215,151
Kansas	206,905	465,671	227,120
Kentucky	1,043,295	500,180	400,724
Louisiana	364,083	643,163	567,562
Maine	120,990	60,843	128,814
Maryland	275,304	236,869	329,589
Massachusetts	324,831	245,638	467,950
Michigan	763,305	648,979	831,357
Minnesota	216,550	332,601	425,669
Mississippi	275,644	267,176	237,513
Missouri	1,209,475	498,767	571,308
Montana	153,517	127,277	214,526
Nebraska	70,867	156,978	152,970
Nevada	134,406	87,923	85,228
New Hampshire	98,415	53,485	94,337
New Jersey	281,186	491,451	634,714
New Mexico	238,186	230,530	173,344
New York	789,529	668,454	1,053,231
North Carolina	594,742	483,235	557,052
North Dakota	104,681	123,460	48,332
Ohio	2,432,447	1,104,595	908,214
Oklahoma	94,500	411,015	294,848
Oregon	50,791	205,720	308,700
Pennsylvania	1,722,749	944,884	1,006,961
Rhode Island	12,853	32,888	73,523
South Carolina	312,950	252,281	430,748
South Dakota	37,070	71,991	86,764
Tennessee	1,050,659	482,020	503,136
Texas	1,201,451	3,020,958	1,971,544
Utah	105,791	141,300	145,560
Vermont	7,425	21,573	53,135
Virginia	336,366	347,845	478,765
Washington	288,295	267,298	422,143
West Virginia	1,039,200	418,225	140,415
Wisconsin	608,367	369,926	432,701
Wyoming	191,538	225,805	92,964
Contiguous U.S.	24,452,870	20,390,304	21,078,895

SECTION 5

FUTURE TRENDS IN EMISSIONS IN THE 1980s

In this section, some discussion is presented on the likely trend of SO_x, NO_x, and VOC emissions in 1986 and 1987. The discussion is primarily qualitative in nature. The objective is to discern how (1) overall levels of economic activity, (2) types of economic activity, and (3) trends in the quantities of emissions associated with these activities will interact in the near future, as opposed to making a specific numeric projection.

In analyzing these trends, we have assumed a GNP increase for 1986 of 2.6 percent compared to 1985 and a further increase of 2.3 percent for 1987 over 1986 (Industry Week, 1986). These figures compare to an increase of 2.7 percent for 1985 over 1984. Furthermore, we have assumed that the world oil price will be approximately $20 per barrel and that there will be no other unusual events which would disrupt economic activity.

ELECTRIC UTILITIES

Electricity generation in the first seven months of 1986 was relatively close to 1985 levels. Coal production (80 percent of which is consumed by utilities) through November 1986 was within a percentage point of 1985 levels. Oil use by utilities in 1986 increased somewhat due to lower oil prices. This increase in oil use offset, to some extent, coal-fired generation but these increases do not appear to be of major significance.

Over the long run, utility emissions will be affected by the speed at which new coal-fired units meeting the NSPS limitations replace existing units. Current power generation systems can meet today's environmental standards but offer no significant improvement over older units in terms of efficiency in the conversion of heat energy in fuel to electricity (termed heat rate). Some new technologies have the promise of meeting environmental requirements while also providing improved performance, but commercial introduction and application of such technologies is many years away. This is because new technologies will have to provide either a significantly increased efficiency or lower cost to justify replacement of current facilities.

Over the one- to two-year forecast horizon being considered here, changes in demand for electricity must be met by corresponding changes in the utilization of existing plants and some capacity additions. The oil embargo of 1973-1974 and resulting changes in energy prices have had a long-lasting effect on the utility industry in this country, an effect which continues through the present. Previous growth rates of 7 percent per year in electricity demand have fallen to about 1 to 2 percent per year. Since new plants must be planned from 10 to

20 years in advance, a large amount of new capacity, which is no longer needed, has been (and still is) coming on-line. While some plants have been cancelled and others deferred, some have been brought into service, depressing overall industry capacity utilization far below historic (pre-1974) levels. Were capacity utilization of older units regulated under State Implementation Plans to increase to pre-1974 levels, utility emissions of SO_x would be expected to increase by about 20 percent above current levels. Such increases do not appear likely through 1987 since reserve margins remain high (and capacity utilization low) in those regions which have high-emitting plants which are also underutilized. Since emission rates between highly controlled and high-emitting uncontrolled power plants can differ by more than a factor of 10, the potential exists for relatively large increases in emissions even in the absence of large increases in demand for electricity.

For NO_x, the difference in emissions between typical, well-controlled coal-fired plants and uncontrolled plants is about a factor of two. As a result, changes in NO_x emissions are not as greatly affected by changes in patterns of utilization, as opposed to total utilization as measured by fuel consumed.

If there are no major changes or disruptions in relative fuel economics, 1987 national utility coal combustion is likely to be within about 5 percent of 1985 levels. If recent trends continue, the major growth areas will be in regions which have plants with relatively low emission rates. This would tend to suggest a relatively small change in SO_x emissions although the magnitude and even direction of the change from 1985 will depend upon regional growth patterns which were not analyzed in detail as part of the present study.

INDUSTRIAL ACTIVITIES

Smelters

As indicated in the discussion of historic trends of SO_x emissions from smelters, several factors affect the likely trend in future SO_x emissions. These factors include economic activity, the implementation of environmental regulations, production costs, and international competition. The following factors will be important in determining future emissions trends.

- Environmental controls -- Beginning in January 1988, stringent emission regulations must be met by operating smelters. Because the installation of controls is very expensive ($65 million to $200 million), the likely effect of the regulations is to further centralize copper smelting in a few, efficient plants (Jolly and Edelstein, 1984). Emissions will drastically decrease in some areas (essentially to zero), but could increase in other regions depending on the extent to which production shifts from one region to another.

- Foreign competition -- Foreign smelter production has increased fairly steadily since 1982, and it is expected that Third World countries will continue to mine and process all the copper they can. Generally, however, Third World copper production is already at or near capacity (Standard & Poor, 1986b). As smelters have been shut down in the United States, startups have been occurring in the near border regions of Mexico. These emissions may adversely influence air quality in the United States, although a recently signed agreement with Mexico to control smelter emissions should mitigate these effects. To the extent that demand remains stable or increases, then, domestic smelter operation may rise steadily to meet any supply shortfall. An increase in emissions would also be expected, although influenced by environmental regulations.

- Copper demand -- Continued low interest rates have supported the domestic construction industry, the major user of copper (about 40 percent of all copper) (Standard & Poor, 1986b). Other demand sectors are also likely to remain strong as long as the economy grows steadily. The weaker dollar makes domestic copper a relatively better buy, and may reduce the amount of copper imported to this country, which is currently and has been historically (since about 1975) significantly higher than the amount of domestic copper exported to other countries.

- Production costs -- The implementation of environmental controls has increased production costs significantly. To some extent, these costs have been offset by reduced labor costs resulting from renegotiated labor contracts; generally low production levels in the 1980s have resulted in labor union concessions or even decertification.

- Competing technologies -- A low-cost, solvent extraction electrowinning process of recovering copper from ore, which does not require smelting, is a possible competitor to the generally used process. This newer technology, which would help reduce SO_x emissions, is not expected to make significant inroads domestically, however, because it can only be used with oxide ores; the bulk of U.S. copper ores are sulfides, requiring smelting (Standard & Poor, 1986b).

Petroleum Refineries

Industry sources do not predict any major change in domestic petroleum production (Standard & Poor, 1985). U.S. gasoline demand is projected to fall 1 percent per year for the remainder of the century. This decline in gasoline will be accompanied by modest rises in residual oil use and other products in the petrochemical field. Oil industry restructuring, industry downsizing of programs, and shrinking profits will probably result in additional plant closings. The result of these changes in production and operating plants will yield little or no change in SO_x emission levels beyond those observed in the 1981-1985 time frame.

Iron and Steel

Although U.S. steel production is down and faces financial difficulties and competition from foreign markets, it has achieved a 20 percent reduction in costs over the last three years due to mill closing and employee cutbacks. This streamlining has included transfer of manufacturing capacity abroad to take advantage of lower labor and materials costs.

Increased production, with resultant increases in emissions, depends upon several factors, however. Domestic production for 1986 is expected to be below 1985 levels (Standard & Poor, 1986a). Operating rates may remain at the current reduced levels of 65 percent and this means that profitability depends almost solely on rising prices, which in turn depend upon fewer imports, a lower dollar against foreign currencies, and stable to slightly lower interest rates. Improvement in the general economy has so far bypassed the steel producers and a world-wide surplus of steel production has pushed down international prices.

TRANSPORTATION

The focus in the transportation sector has been the highway vehicle component. With the trends in NO_x and VOC emissions observed from 1980 to 1985, there is little expectation that emissions from highway vehicles would be expected to decline in the near future. Only gasoline shortages or much higher fuel prices, which would reduce VMT growth, would serve to provide highway vehicle emission reductions given the current set of emission standards. It is probable that the phase-out of leaded gasoline will eliminate misfueling and its consequent emissions impacts. Light truck and heavy-duty engine NO_x emission standards became more stringent with the 1987 model year, but these standards are expected to reduce the rate of growth in future NO_x emissions rather than provide a reduction from current NO_x emission levels.

OTHER SOURCE CATEGORIES

Although residential wood combustion has experienced significant growth over the 1980 to 1985 time period, this increase is likely to level off at least in the short term for a number of reasons. Since wood competes with oil and natural gas, the decline in oil and gas prices will likely result in both reduced installations of wood-burning equipment as well as reduced use of existing equipment in homes equipped with other units for backup. Over the longer term, local emission regulations plus the Federal New Source Performance Standards for wood stoves should serve to reduce the contribution of this source type to total VOC emissions.

Trends in future national and regional VOC emissions from forest fires and prescribed burning are to some extent dependent on U.S. Forest Service policies regarding when and where prescribed burning takes place. As these activities are seasonal, the Forest Service policy decisions will affect when within the year much of these emissions occur.

SECTION 6

METHODOLOGY AND COMPARISON TO OTHER DATA

TYPES OF EMISSION ESTIMATES

In this section, the various methods used by EPA to estimate emissions are introduced and explained. The rationale for the use of various methods is explained. The results of the present study are put into context with the overall emissions data base development plan now being implemented by several offices of EPA.

In developing comprehensive emissions data bases, emissions must be estimated from surrogate variables rather than measured directly. While the direct measurement of emissions is technically possible, the costs of measurement and the large number of sources make it impracticable to directly measure even a small share of total emissions.

Within the past few years, there has been increased awareness and concern regarding possible adverse effects from the long-range transport of pollutant emissions, effects which can occur even if ambient standards are being achieved at and near the point of discharge. In addition, proposed legislation has been introduced and considered in Congress which would limit total emission tonnages. As a result, the various headquarters and regional offices of EPA as well as state and local air pollution control agencies are cooperating to improve emission estimates. Some of the products which will result from these joint programs are discussed later in this chapter.

Typically, two types of methods have been used to estimate levels of emissions. These two methods can be summarized as top-down and bottom-up. The two types of methods are not totally incompatible since they share some key aspects. The basic procedure shared by both methods involves the use of emission factors as a key step in estimating emissions which, as discussed above, are generally not measured, but are based on other economic activity data that are measured. Simply put, an emission factor is a number that relates units of measured economic activity to estimated quantities of pollutants that would be discharged in the absence of control equipment. Typical emission factors are in units such as pounds of SO_x per ton of coal burned or pounds of VOC per ton of solvent used. Emission factors can be developed using a variety of methods and combinations of methods, including stack test measurements and material balance calculations, to mention two common methods. Accuracy and precision are influenced by the method used, the number of samples taken, the appropriateness of the categories selected, the representativeness of the samples used to derive the factor, and numerous other elements. Given the emission factor, emissions can be estimated knowing the underlying level of economic activity and the removal associated with any control equipment in place.

The bottom-up method of estimating emissions attempts to estimate activity on a source-by-source basis. Each major emitting source is identified and detailed information is collected concerning activities having the potential to emit air pollutants. A major industrial plant may have hundreds of such activities. In addition to the type of activity, information is needed about its operating rate and any applicable controls. For those cases in which emissions result from the combustion of fuel contaminants, (e.g., sulfur in coal), information on the level of contaminant is also needed. For example, the estimation of SO_x emissions from the pulp and paper industry would require knowledge of all of the applicable producing facilities, their levels of operation, the quantity of sulfur in their fuels, and the efficiency of any control equipment used to reduce emissions. Since there are more than 10,000 identified sources in the United States which may emit more than 100 tons per year of one or more pollutants regulated by EPA, collection of data for a bottom-up emissions estimate is a massive task. To produce an annual data set requires updating at least some of this information (operating rate) for every facility for every year.

The top-down method works by using aggregate statistics of economic activity. These are then multiplied by the appropriate emission factors to estimate uncontrolled emissions and an adjustment is then made for pollutant removal due to control equipment in place, resulting in an estimate of emissions released to the atmosphere. Estimating SO_x emissions from the pulp and paper industry would require information on total production (by source type), and control equipment in place. When top-down methods are used to estimate national emissions, regional estimates are then estimated by disaggregating the national figures using regional estimates of economic activity.

While bottom-up methods are more accurate if all of the needed information is available, collection of such a massive amount of information using consistent definitions is extremely difficult.

Within EPA, the Office of Air Quality Planning and Standards (OAQPS) has maintained and updated NEDS for a number of years and produced annual "snapshot" files containing detailed source-specific information. The National Emissions Data System operates in a decentralized fashion with individual state air pollution agencies and EPA regional offices having the key responsibilities for data acquisition. OAQPS maintains the national data base as an amalgamation of state submittals.

While annual NEDS data files are available, they are generally not appropriate for conducting longitudinal analyses of emissions trends such as those presented in this report. Historically, the quality of individual state submittals has been highly variable and, in most cases, complete data on operating rates for entire years are simply not available.

In addition to maintaining NEDS, OAQPS also produces an annual national estimate of emissions by source category. This national Trends estimate is calculated by using aggregate economic statistics and emission factors as discussed above. As an analysis of emission trends is meaningful only when there is a common basis for evaluation, it is necessary to establish emission estimation procedures that use the same criteria for each year. The national Trends procedures were established to meet that objective.

In summary, Trends is most useful in providing a consistent methodology to estimate emissions over a number of years, while NEDS is capable of providing detailed and accurate emission estimates for a specific year.

Figures 37 through 39 compare the Trends results used in this study with aggregated data from the 1980 NAPAP emissions data base which was based on the 1980 NEDS data. One of the major difficulties in comparing these estimates is that not all operating rate/emissions data in the 1980 NAPAP data base actually reflect the year 1980. The 1985 NAPAP emissions data base will overcome these problems.

For SO_x, (Figure 38) both methods produce similar estimates. Utility estimates differ slightly due to differences in assumptions regarding scrubber operations. NAPAP values are slightly higher for industry and the "other" category but are lower by a minor amount for transportation. These differences are certainly within the bounds of uncertainty in emissions estimates.

NO_x estimates generally have more uncertainty than those for SO_x and this is apparent in Figure 38 which compares Trends and the 1980 NAPAP emissions data base. Utility numbers differ slightly due to differences in assumptions regarding efficiency and extent of control equipment. For industry, NAPAP estimates are higher, probably due to differences in assumptions concerning operating rates. Transportation sector differences are due to somewhat different assumptions regarding average vehicle speed distributions. Most of the emissions in the "other" category are from fires and few accurate data are available on emissions from this source.

The VOC emissions (Figure 39) reflect even more uncertainty. A major problem in estimating VOC is the estimation of evaporative losses in industrial processes. The Trends estimates incorporate greater levels of activity in several key categories than are present in the NAPAP emissions data base.

Allocation factors have been applied to the 1980 NAPAP emissions data base to resolve the annual emissions further with regard to space, time, and chemical species (Wagner et al.,

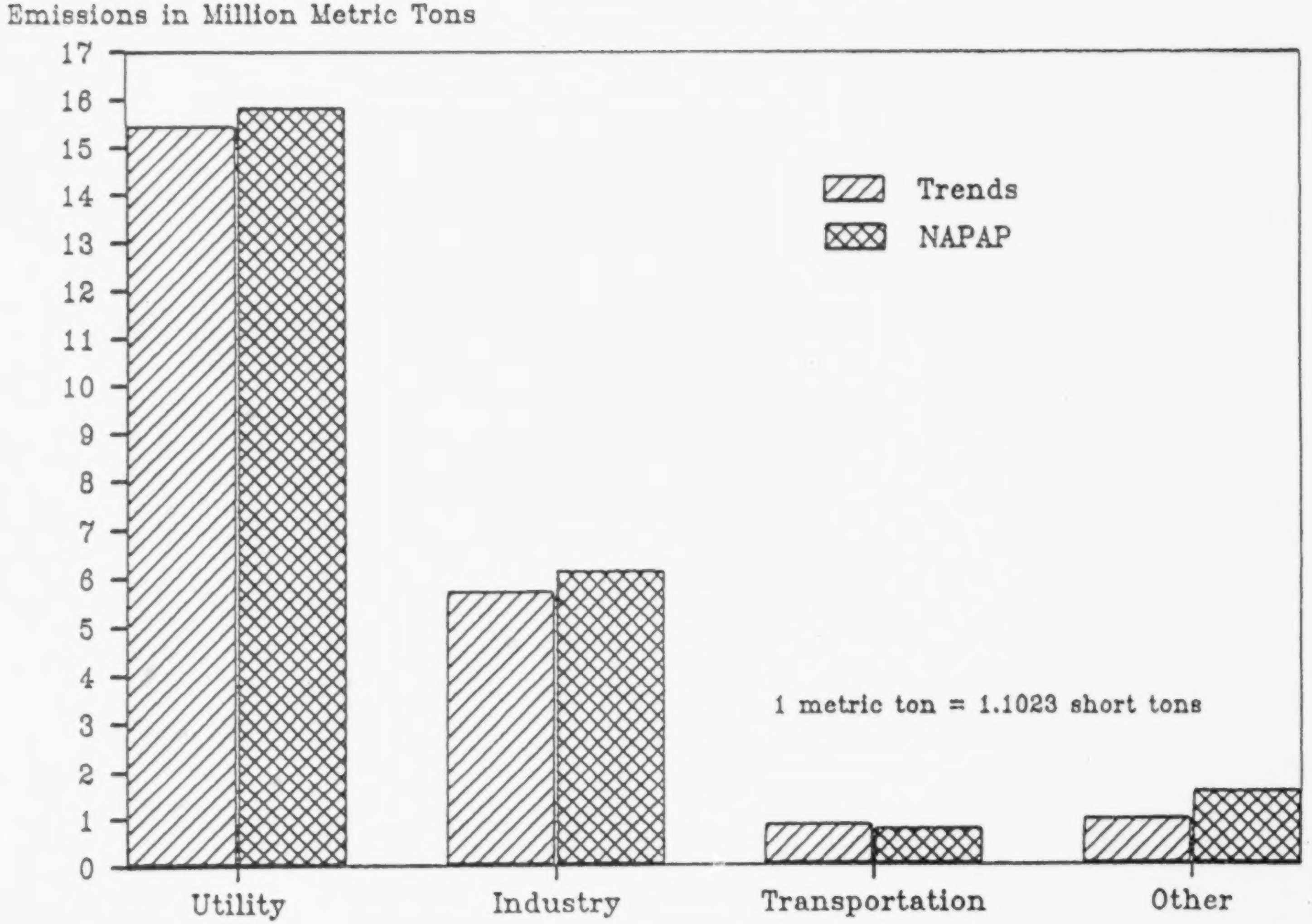


Figure 37. United States SOx emissions by source category

-- Trends and NAPAP (1980).

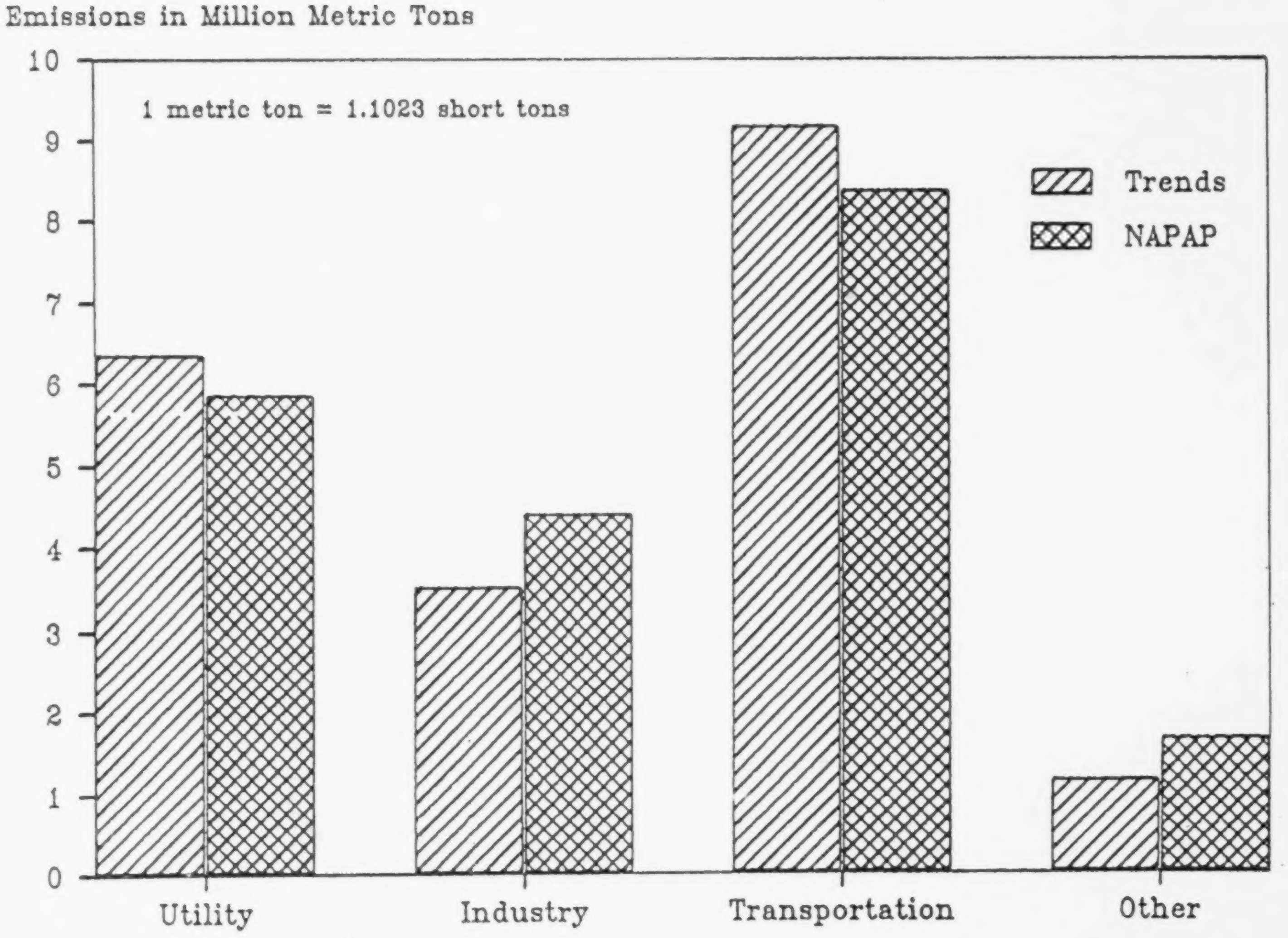


Figure 38. United States NOx emissions by source category -- Trends and NAPAP (1980).

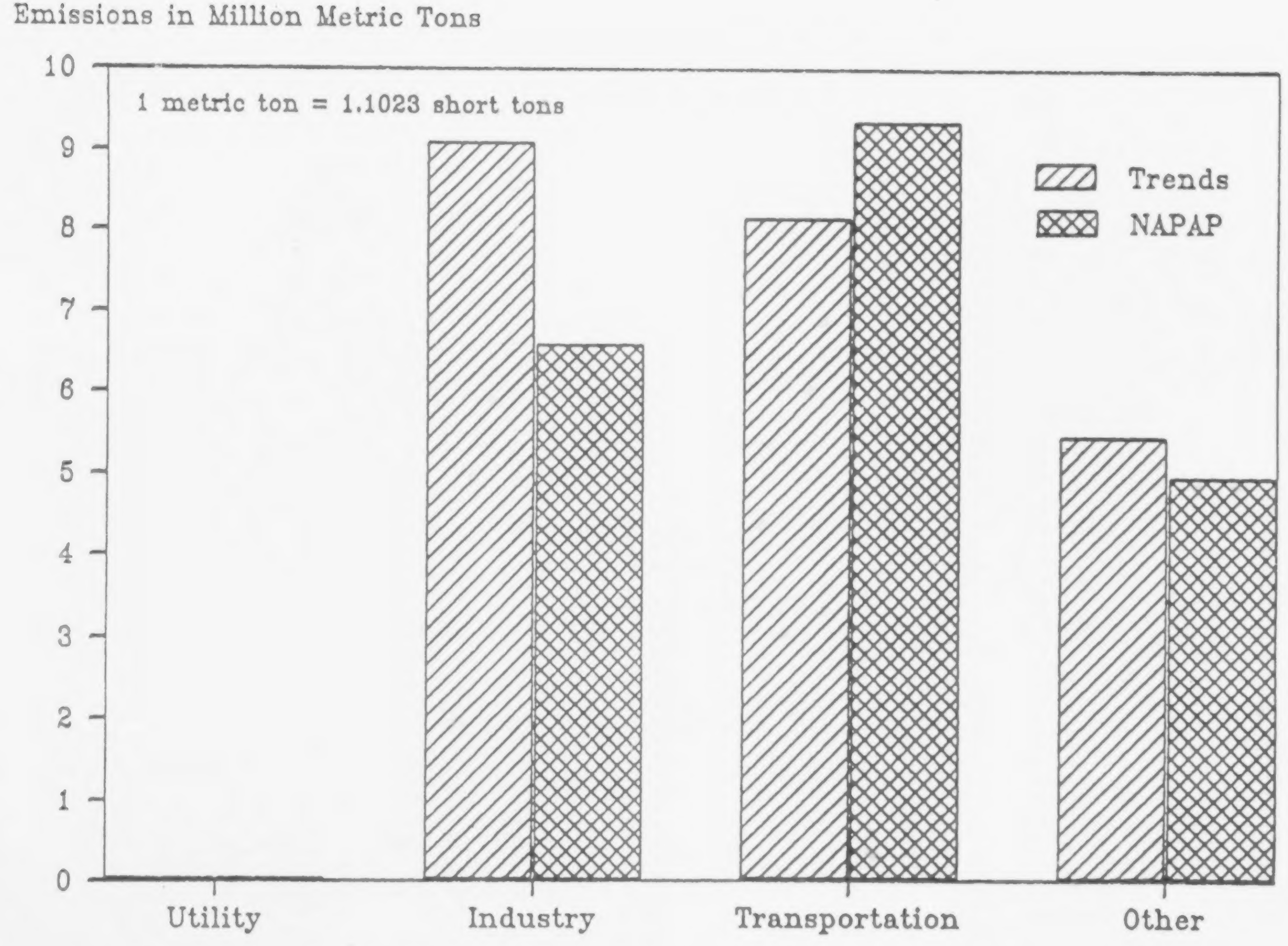


Figure 39. United States VOC emissions by source category -- Trends and NAPAP (1980).

1986). Figures 40, 41, and 42 depict the spatial distribution of SO_x, NO_x, and VOC emissions, respectively, for a "typical" summer weekday, and clearly demonstrate the concentration of emissions in the industrial midwestern and eastern United States. Similar levels of emissions resolution will be applied to the 1985 NAPAP emissions data base currently being prepared and not available for inclusion in this study. A much greater effort at consistency and quality control is being made for the 1985 emissions data base which should provide a valuable benchmark to which Trends estimates can be compared in detail.

DESCRIPTION/DEFINITION FOR EACH MAJOR EMITTING CATEGORY

Utility emissions of SO_x have been computed on a plant basis for individual years (Pechan, 1982) and unit-level estimates of SO_x and NO_x were estimated for 1980 as part of the development of the NAPAP Utility Reference File (Pechan, 1986b). More recently, monthly state-level utility emissions estimates were computed covering the period from 1973 through 1985 (Pechan, 1986a). As part of the present study, national totals from these estimates were compared with Trends results. Differences were relatively small and could be explained by minor methodological differences. In order to produce estimates consistent with the Trends methodology, adjustments were made in the state-level monthly data. The adjusted results were used in this report.

Utility fuel consumption data are reported on a monthly basis to the Federal Energy Regulatory Commission (FERC) and these figures form the basis for estimating utility emissions. The utility fuel consumption data series is considered to be of very high quality. Information on fuel consumption and other important determinants of emissions such as fuel quality (for SO_x) and burner firing type (for NO_x) are obtained from other mandated utility reports. Since the majority of the data on utilities which are used to determine emissions are directly reported, the resulting estimates have a relatively higher degree of assurance than estimates which must depend upon statistical relationships or sampling (such as fuel consumption by non-utility sources).

Copper smelter SO_x emission estimates were developed using plant data where available (first preference), published state totals (second preference), or assumptions about the relationship among copper production, plant level SO_x control efficiencies, and SO_x emissions. Plant level SO_x emissions were available for the Arizona smelters (seven plants) and the ASARCO smelter at Tacoma, Washington (Nolan, 1986). Published state level values were available for Utah, Nevada, and New Mexico. Estimates for the remaining smelters were available for 1980 from the U.S./Canada Work Group 3B report (1982) and from a GCA analysis for 1985 (Brostrom and Battye, 1986). Emissions of these remaining smelters were estimated for 1981-1984 using National Trends report values and what was known about emissions from smelters in the states with data.

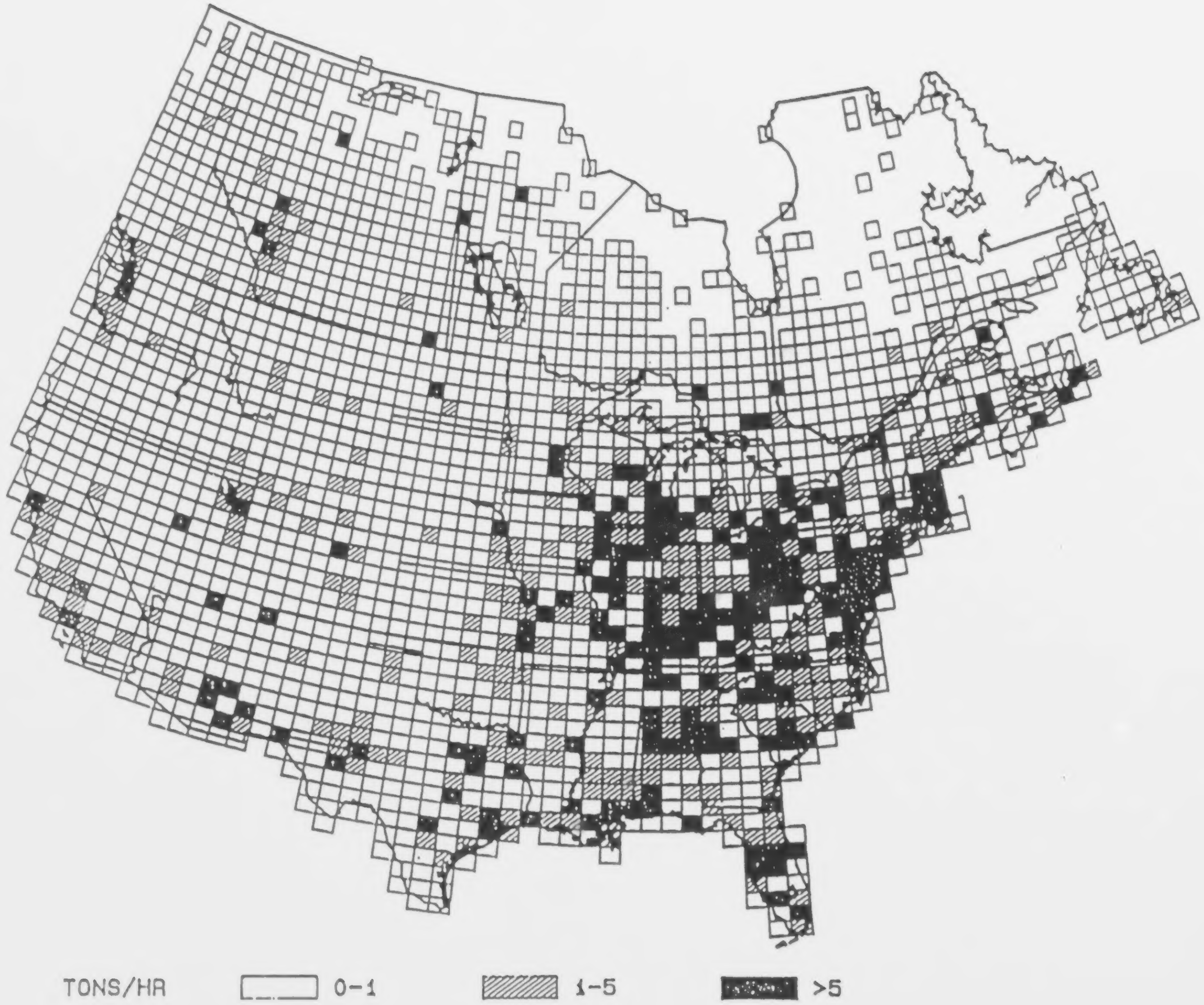

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Figure 40. 1980 NAPAP Emissions Inventory Version 5.2 -- SOx emissions for a typical summer weekday at 1700 GMT.

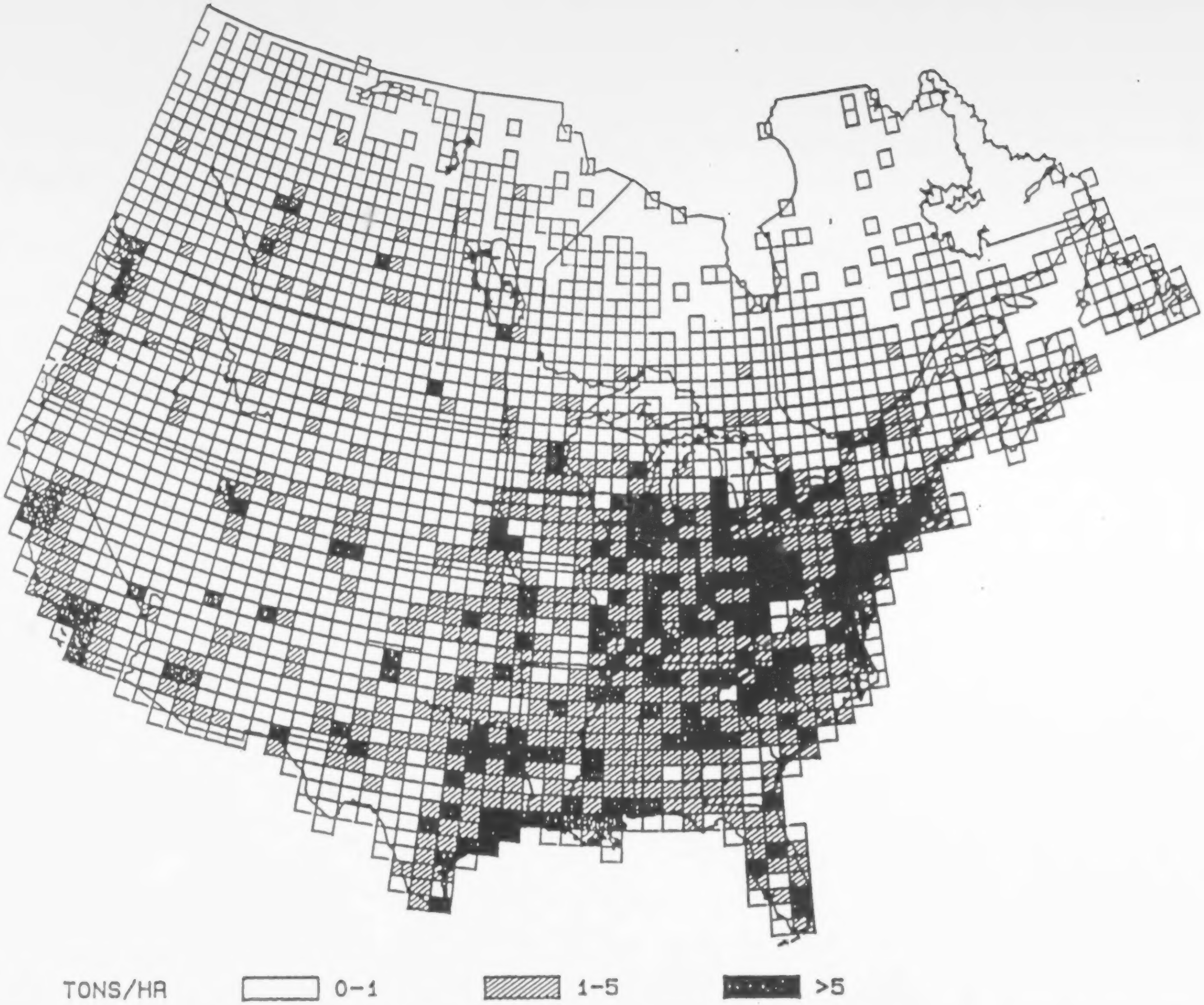
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Figure 41. 1980 NAPAP Emissions Inventory Version 5.2 -- NOx emissions for a typical summer weekday at 1700 GMT.

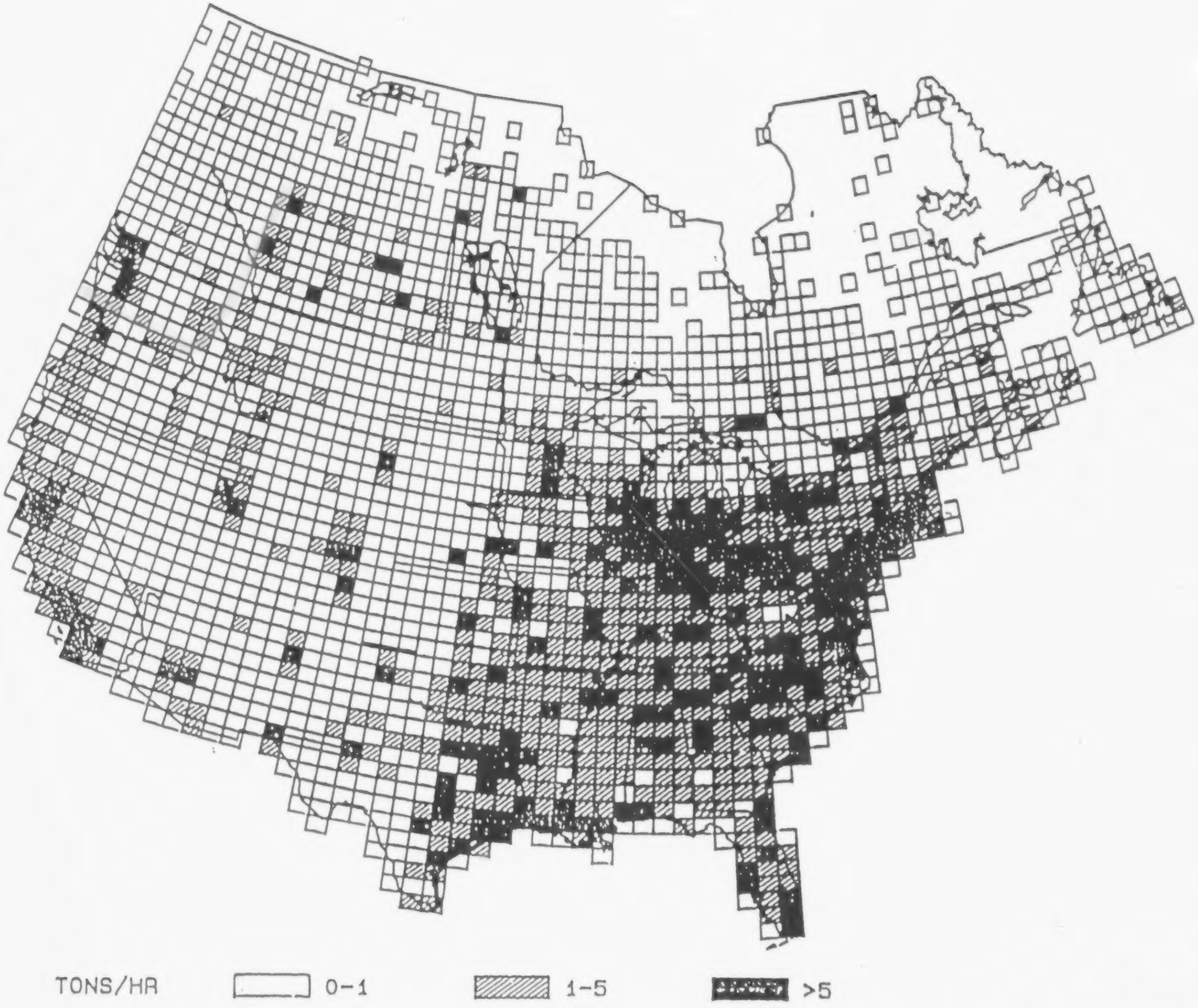
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Figure 42. 1980 NAPAP Emissions Inventory Version 5.2 -- VOC emissions— for a typical summer weekday at 1700 GMT.

Highway vehicle SO_x, NO_x, and VOC emissions were allocated from the national to the regional level using annual VMT by state by year (U.S. Department of Transportation, 1986). No attempt was made to account for differences in emission rates in California or high altitude areas or to adjust highway vehicle VOC and NO_x emissions to account for regional differences in annual average temperatures.

Industrial, commercial, and residential fuel combustion emissions were estimated using State Energy Data System (SEDS) values for 1980 through 1984 (U.S. DOE, 1986b). The State Energy Data System reports state level fuel combustion by fuel type. Values for coal, natural gas, and total petroleum were used in this study. Fuel use estimates were not available from SEDS for 1985. Data on the domestic distribution of coal in 1984 and 1985 by destination (state) to other industrial plants, and residential and commercial sectors were used to establish a relationship between 1985 and 1984 coal deliveries (U.S. DOE, 1986a). These ratios were then applied to 1984 SEDS values for coal to estimate 1985 non-utility coal use. SEDS data are based on statistical relationships and results from sampling surveys; as such, they have a lower degree of assurance than utility fuel consumption data. Also, SEDS does not contain information on the type of use to which reported fuels are put and this introduces a considerable amount of uncertainty. For example, emission factors for NO_x combustion, expressed in emissions per unit of fuel consumed, can vary by more than a factor of 10. To address this issue, 1980 average regional emission factors were used for the 1981-1985 years.

SEDS does not include estimates of residential wood combustion, so data from a recent DOE-EIA study were used to estimate the distribution of wood combustion emissions by region (U.S. DOE, 1982). Residential wood combustion by state was only available for 1980 and 1981, so the 1980 distribution was assumed to apply to all study years.

Regional estimates of emissions arising from iron and steel production were made using data on the domestic distribution of U.S. coal to coke plants by destination (U.S. DOE, 1986a). Coal deliveries (in tons) to coke plants by state were then used as a surrogate for iron and steel plant emissions. This should provide a reasonable breakdown of SO_x emissions by region as most of the SO_x emitted by iron and steel-making processes comes from coke ovens. Regional estimates of emissions from this industry may not be as accurate for other pollutants.

Petroleum refinery emission estimates by region were allocated from the national totals using state refining capacities by year (Oil & Gas Journal, 1980-1985). Statistics on wood pulp production by region were used to estimate regional changes in pulp and paper facility emissions during the study period (American Paper Institute, 1986). Pulp production statistics were only available for four areas in the United States (Northeast, North Central, South, and West) so each of the 10 EPA regions was assigned to one of the four pulp and paper areas for estimating regional emission shifts.

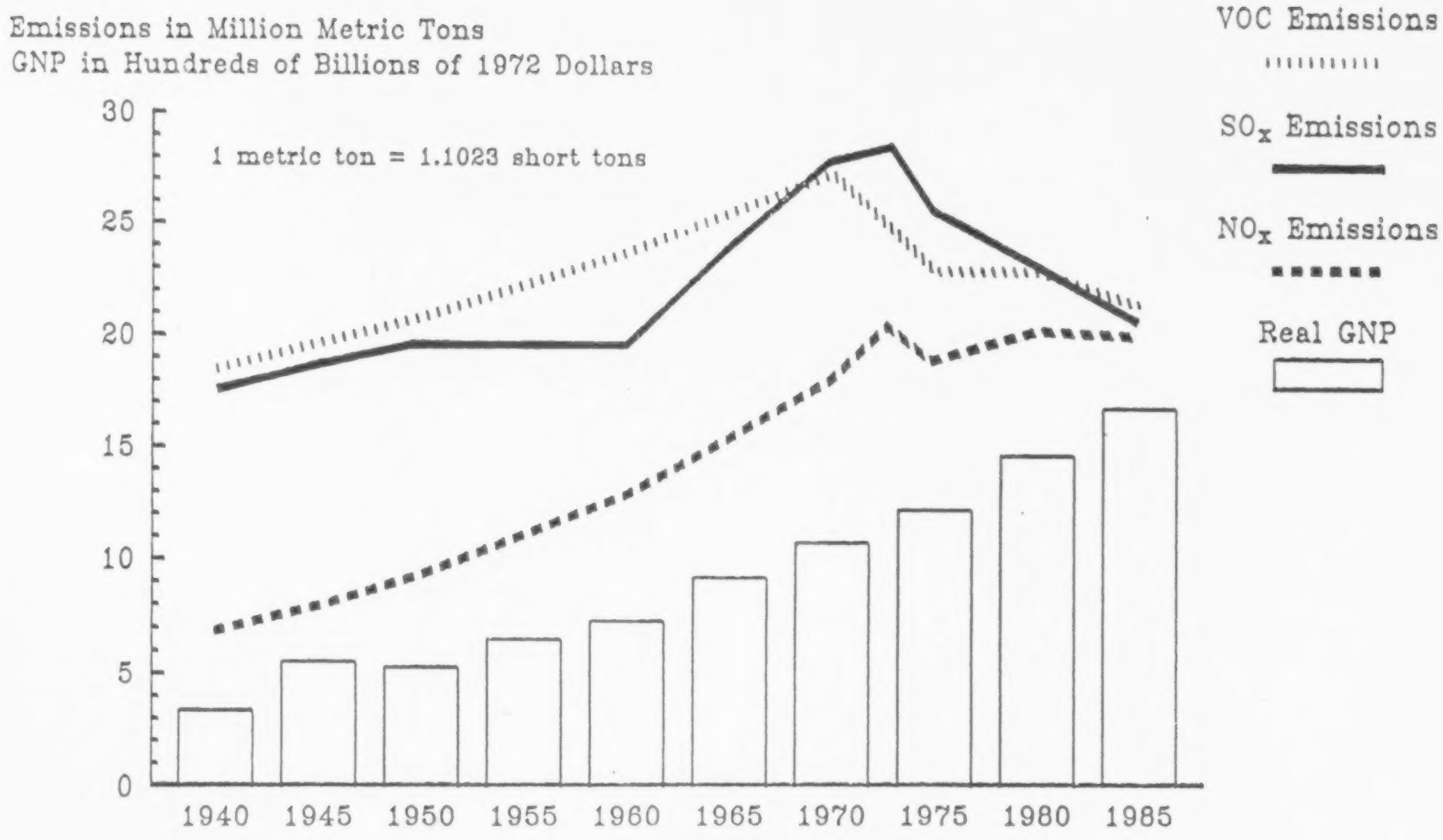

Figure 43. United States emission and GNP trends (1940–1985).

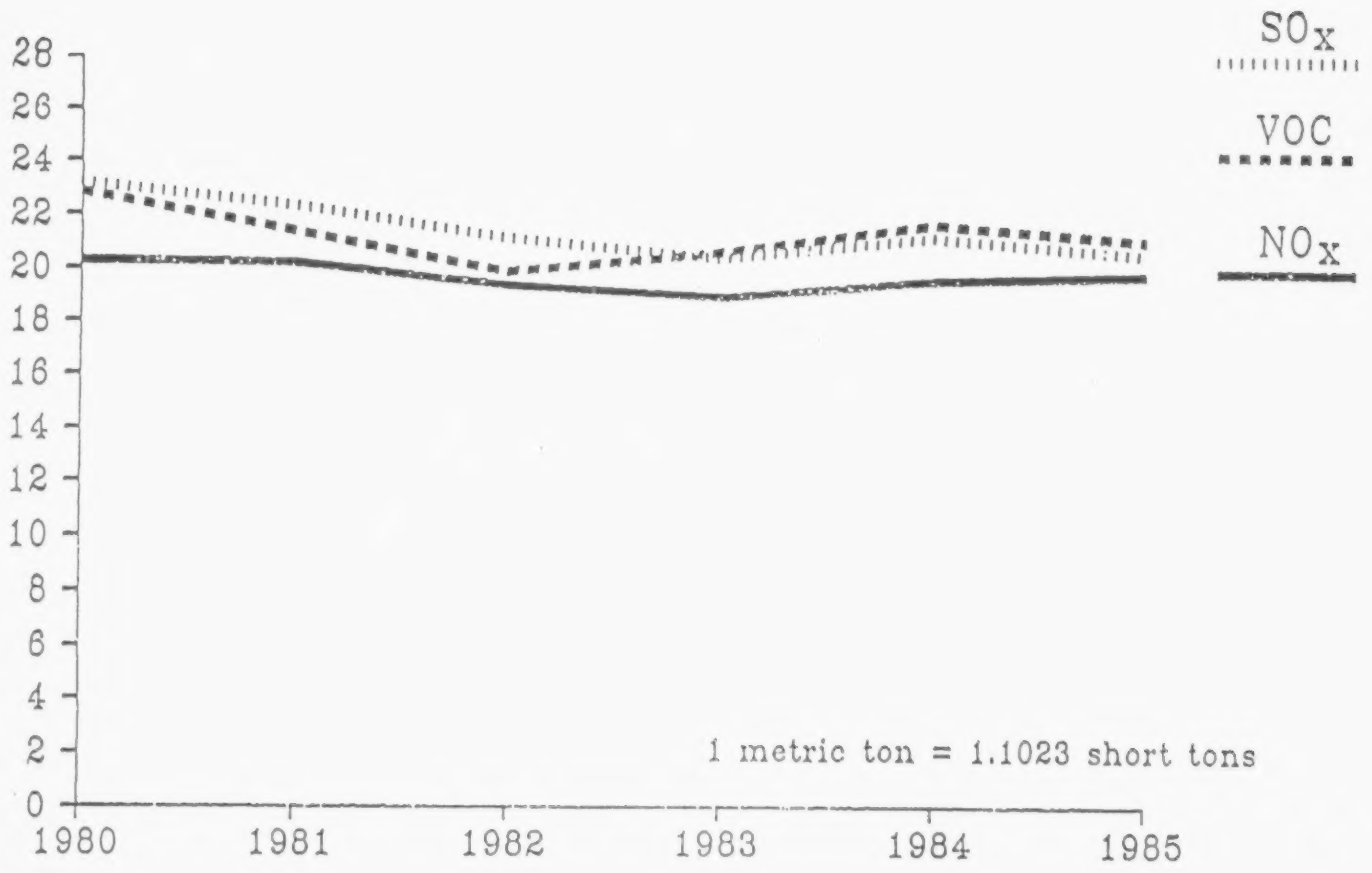

Figure 44. United States emission trends (1980–1985).

SECTION 7

EMISSION TRENDS

U.S. EMISSION TRENDS FROM 1940 TO 1985

New Information Since 1983

Historical and current emission trends can be reasonably well represented by three time segments, as shown in Figure 43. Most recently, the relationships between emissions and the economy, fuel use and pollution control regulations have become more complex--in contrast to the emission trends evidenced before the early 1980s.

Significance of New Information

It is now extremely difficult to analyze how economic growth, fuel use, and pollution control regulations have affected and will affect man-made emissions. The difficulty of predicting emission trends for the next five or more years has created controversy among those interested in and affected by environmental regulations about whether emissions will increase or decrease during this period. Similarly, this difficulty has fostered controversy about the effect of existing environmental regulations on these emissions and whether additional or fewer regulations are needed.

Explanation for Change

Emission trends since 1940 break down into three periods. The 1940 to mid-1970s period (Figure 43) was one of emissions growth in which, generally, emissions increased proportionately with fuel use and GNP. The latter half of the 1970s and the early 1980s was the "emissions control era" in which programs enacted under the Clean Air Act produced a downward emission trend for all pollutants, except NO_x, while the economy and fuel consumption continued to grow. As shown in Figure 44 (discussed below), the relationships between emissions, the economy, fuel use, and regulations became more complex after 1983.

The main reason for this added complexity is that many emission reductions were achieved in the 1970s and early 1980s, and few new programs have been instituted since then to go beyond those control levels. While many new large emission sources are controlled via NSPS, providing consistent reductions throughout the United States, the operation and control of pre-NSPS units have a significant effect on emission trends. Since existing unit regulations emphasize solving nonattainment problems, regulations can be state-, county-, or even plant- or source-specific. All of the above serve to make future emission trend estimation a complex task.

Economics also have an important effect as declines in commodity prices and foreign competition in the 1980s have adversely affected industrial production levels in a number of mineral production and heavy manufacturing sectors, resulting in reduced air emission levels, with copper smelters and iron and steel mills being the best examples. Fuel and capacity utilization choice decisions in the utility and industrial sectors have also been affected by electricity demand and price differences among coal, oil, and gas.

U.S. REGIONAL EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

Pollutants and regions dominated by large point sources show the most year-to-year variation in emission levels. Dominant point source categories include electric utilities and copper smelters.

Significance of New Information

Regional emission patterns often follow national trends, but there are exceptions which must be noted when source-receptor relationships are explored for particular geographic areas or regional concerns. For example, U.S. regions bordering eastern Canada have experienced reductions in SO_x emissions from 1980 to 1985 consistent with the nation as a whole, while a copper smelting region in the southwest experienced a much larger SO_x emission reduction.

Explanation for Change

All federal regions had SO_x emissions decreases from 1980 to 1985, except Regions 6 and 8. Total reductions of SO_x from 1980 to 1985 were highest in Regions 3, 4, and 5, but these were also the highest SO_x emitting regions in 1980. Consequently, they all reduced their SO_x emissions at about the same rate as the national average in this period. Regions 2 and 9 had the largest percentage declines in SO_x, both about 25 percent. Region 9 decreases were primarily due to production declines at copper smelters.

Regional NO_x emission trends from 1980 to 1985 were generally downward in the eastern United States and either flat or upward in the west. Control regulations for NO_x are not as prevalent as they are for other pollutants, so, except for mobile sources, NO_x emissions track almost directly with fuel use. Regional highway vehicle emission trends were similar to those observed nationally, with regions having the highest VMT growth showing the least decline in emissions.

Regional VOC emission trends all seem to be similar to those observed at the national level. This lack of regional variation results from both the absence of dominant source types and the uncertainty in estimating VOC emissions.

CANADIAN EMISSION TRENDS FROM 1970 TO 1984

New Information Since 1983

Data on eastern Canadian emissions of SO_x (20 percent of U.S. levels in 1980) show that emissions decreased 44 percent between 1970 and 1984; U.S. emissions decreased 24 percent during this time period. Eastern Canadian emissions of NO_x, which were 8 percent of U.S. levels in 1980, increased by 29 percent between 1970 and 1984, with most of this increase occurring by 1974. U.S. NO_x emissions increased by 9 percent from 1970-1984.

Significance of New Information

The significance of this new information is that it provides a useful historical perspective between trends of U.S. and Canadian emissions that could contribute to transboundary transport of acidic air pollution.

Explanation for Change

Data on eastern Canadian emission trends (presented in Figure 45) show a 44 percent decrease in SO_x during the 1970-1984 time period and a 29 percent increase in NO_x emissions during the same period. SO_x emissions in eastern Canada generally decreased until 1934, when emissions from non-ferrous smelters rose 31 percent (from 1982 levels) as production increased. Smelters have historically accounted for over 50 percent of SO_x emissions in Canada, with utilities contributing about 20 percent. The relative contribution of smelters has been decreasing since 1970, while utilities' contribution has increased. NO_x emissions in eastern Canada have remained relatively constant since the mid-1970s, when transportation sector emissions stabilized.

U.S. UTILITY SO_x EMISSION TRENDS

New Information Since 1983

Emissions from coal-fired utility boilers decreased by 4 percent from 1980 to 1985, while total U.S. SO_x emissions decreased about 11 percent. Much of this reduction was achieved between 1980 and 1982.

Significance of New Information

Throughout the study period, SO_x emissions were dominated by electric utilities, with major emitters being coal-fired boilers. SO_x emissions from utilities ranged from 66 to 68 percent of the U.S. total. In key eastern States bordering Canada, the utility share averaged 80 percent of the total. Although utility SO_x emissions have declined in recent years, an increase in the use of higher sulfur coal or uncontrolled utility boilers could rapidly reverse this decline.

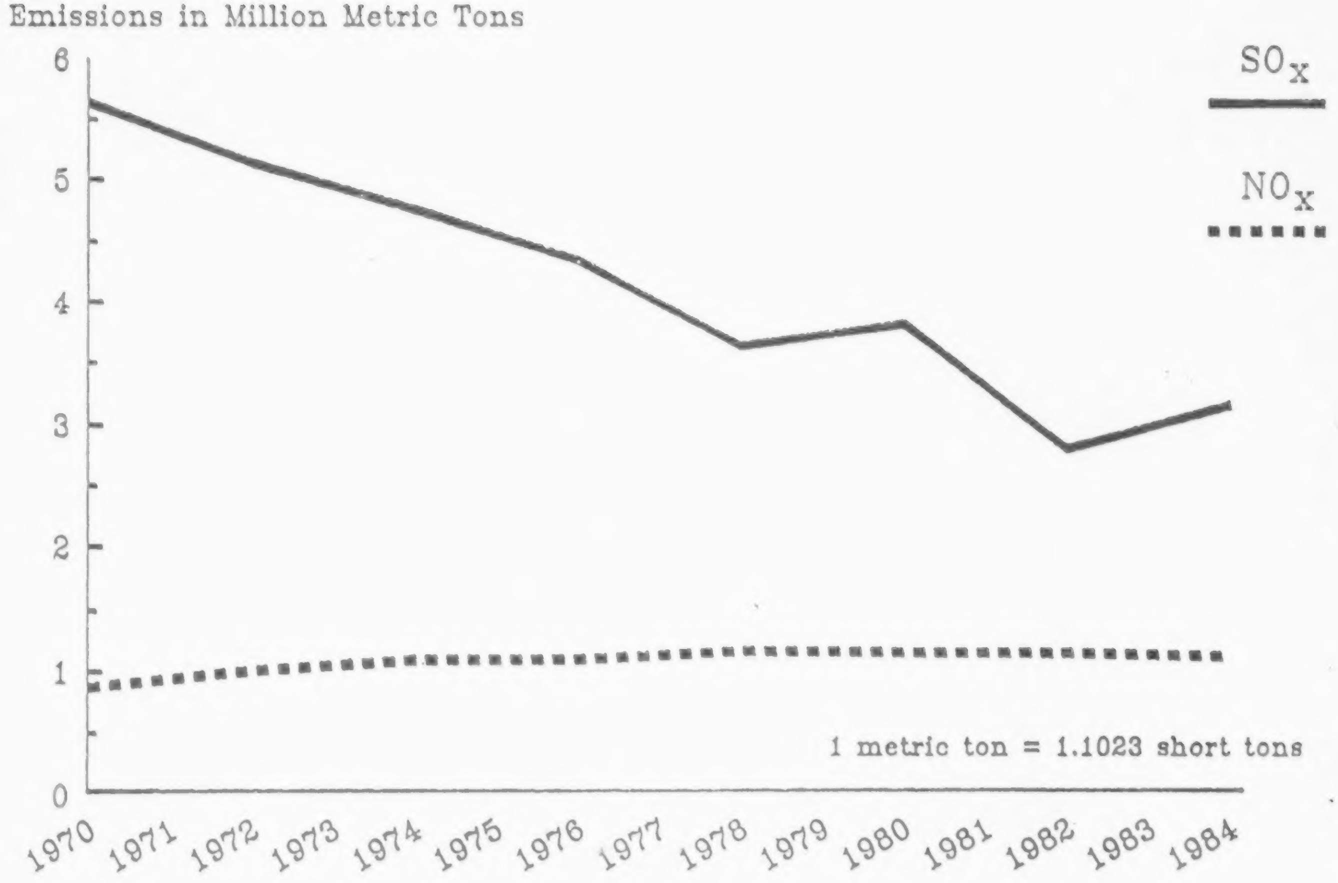

Figure 45. Eastern Canada SOx and NOx emission trends (1970–1984).

Explanation for Change

Coal use by utilities was about 22 percent higher in 1985 than in 1980. Despite this, coal-fired SO_x emissions declined by about 4 percent during this time. These emission decreases, despite increases in potential emissions, were due to two factors: use of lower sulfur coals, and increased use of flue gas desulfurization (FGD) systems. Use of lower sulfur coal reduced 1985 emissions by about 2.4 million metric tons per year, while increased FGD usage resulted in further reductions of 1.4 million metric tons.

Increased low sulfur coal usage results from a combination of factors including (1) growth in electrical demand in areas having ready access to low sulfur coals, (2) increased market penetration of low sulfur coals, and (3) environmental regulations. In the future, coal market forces could reverse the current tendency to use low sulfur coal.

Utility emissions decreased during 1980-1985 due to a combination of economic and regulatory factors. EPA's pre-1983 analysis of future electric utility emission trends indicated that these trends would be primarily a function of two parameters: (1) the replacement of existing sources with new sources subject to NSPS, and (2) the rate of construction of such new facilities. Current analysis of 1980-1985 emission trends indicates that capacity utilization of existing utility boilers has a significant effect on emission levels. For the last several years, utility capacity utilization has been depressed for a number of large eastern utility plants. These are predominantly burning medium-to-high sulfur content coals with no SO_x controls. Possible future increases in the use of these plants to meet increased electricity demand could produce increased emissions.

THE INFLUENCE OF STACK HEIGHT ON THE TRANSPORT OF EMISSIONS

New Information Since 1983

Since 1983, work has begun to distinguish and quantify the difference between emissions released close to the ground and emissions released at higher elevations through "tall stacks." This analysis indicates a significant increase in the tonnages of SO_x emissions released through tall stacks between 1950 and 1980.

While the phrase "tall stacks" refers to not only stack height but also to increased flue gas exit velocity and temperature, the data presented here are limited to physical height only.

Significance of New Information

The significance of emission trends must be balanced by an understanding of the fate of the emissions. Although emission trends analysis indicates an historic decrease in SO_x emissions, this decrease may be counterbalanced by an increase in the amount of SO_x emitted through tall stacks and thus more directly available for long-range transport.

Explanation for Change

Increases in physical stack height and in emission stack parameters such as flue gas temperature and exit velocity increase the height to which emission plumes rise. This increases the potential for long-range transport of emissions. For example, in 1980, approximately 30 percent of SO_x emissions were from stacks taller than 240 feet, compared with only 5 percent above this height in 1950. These stack height, temperature, and velocity increases have been made largely to reduce peak concentrations near major emission sources to meet ambient air quality standards without controlling the quantity of SO_x emitted. Comprehensive information on stack height changes since 1980 is not currently available, but when the 1985 NAPAP emissions data base is completed later this year, an analysis of stack height changes from 1980 to 1985 can be performed.

U.S. NO_x EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

There is no demonstrable trend in national NO_x emissions between 1980 and 1985. However, recent estimates of highway vehicle NO_x emissions (which constitute 45 percent of national NO_x emissions) indicate a possible increase in these emissions during 1986 and 1987.

Significance of New Information

This is a change from pre-1983 projections that national NO_x emissions would decrease as highway vehicle emissions decreased. It was thought that transportation sector decreases, the result of increasingly stringent NO_x emission standards, were expected to more than offset any NO_x emission increases from utility and industrial sector fuel combustion.

Explanation for Change

The major contributors to NO_x emissions are highway vehicles (45 percent) and utilities (33 percent). National highway vehicle emission trends show a decline from 1980 through 1982 or 1983 with an upward trend starting in 1984. Utility NO_x emissions followed a similar trend. However, in relation to the methodological uncertainty inherent in the emissions trends analysis for NO_x, there is no observable trend in national NO_x

emissions during the 1980-1985 time period.

NO_x emissions from transportation sources, primarily highway vehicles, were expected to decrease by 9 percent in the 1980-1990 time period before beginning to increase again after 1990. Recent estimates of vehicle miles traveled, age, and emission rates suggest that an upturn in NO_x emissions from the transportation sector may have begun in 1984. VMT of light and medium duty trucks have increased significantly over the past few years as these vehicles have gained in popularity. Because NO_x emissions from these trucks are less tightly controlled than highway vehicle emissions, increases in truck VMT translate directly into NO_x emission increases.

U.S. VOC EMISSION TRENDS FROM 1980 TO 1985

New Information Since 1983

VOC emissions declined only about half as much as earlier projections for this time period indicated.

Significance of New Information

The United States Environmental Protection Agency estimates of VOC emissions prior to 1983 appear to have overestimated the reduction in emissions that would be achieved in response to control programs.

Explanation for Change

Previous expectations were that total national VOC emissions would decline by 18 percent from 1980 to 1990, and that transportation-related VOC emissions might decline by 50 percent during this time period. However, the VOC emission trends between 1980 and 1985 indicate that total and transportation sector emissions declined by 7 and 12 percent, respectively. Lack of significant declines in the transportation-sector-emitted VOC has resulted from more rapid than expected VMT growth, increased popularity of less well controlled new vehicles, and slower than expected vehicle turnover. It should be noted that VOC emission estimates are more uncertain than those for SO_x and NO_x.

EMISSIONS IN THE NEAR FUTURE

New Information Since 1983

Preliminary fuel consumption data for 1986 and the current relationship among coal, oil, and gas prices indicate that emissions of SO_x, NO_x, and VOC are not expected to vary significantly from 1985 levels during 1986 and 1987, although SO_x emissions may decrease slightly.

Significance of New Information

The flat trajectory that SO_x, NO_x, and VOC emission trends followed in the mid-1980s may indicate that without additional control initiatives, future (1990) emissions of all these pollutants will be higher than they are now if fuel use and VMT increase.

Explanation for Change

Electricity generation in the first seven months of 1986 was relatively close to 1985 levels, while coal production (80 percent of which is consumed by utilities) through November 1986 was within 1 percent of 1985 levels. These are key indicators that 1986 SO_x emission levels will be close to 1985 values. In the absence of major changes or disruptions in relative fuel economics, 1987 U.S. utility coal consumption is likely to be within 5 percent of 1985 levels, foretelling a relatively small change in SO_x emissions.

The source category with the biggest influence on future NO_x and VOC emissions is transportation. With the trends in NO_x and VOC emissions observed from 1980 to 1985, there is little reason to expect that emissions from highway vehicles will decline in the near future. Only gasoline shortages or much higher fuel prices, which would reduce VMT growth, would provide highway vehicle emission reductions given the current emission standards.

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APPENDIX A

REGIONAL EMISSIONS

TABLE A-1. SULFUR OXIDE EMISSIONS IN REGION 1

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	354	322	337	319	342	326
Non-utility Fuel Combustion						
Industrial Coal	8	8	14	14	20	19
Industrial Oil	75	67	85	40	45	46
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	2	4	5	4	7	5
Residential-Commercial Oil	78	56	58	34	35	34
Residential-Commercial Gas	0	0	0	0	0	0
Other	1	1	1	1	1	1
Non-utility Fuel Combustion Total	164	136	163	93	108	105
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	9	9	9	8	8	8
Sulfuric Acid (2819)	1	1	1	1	1	1
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	0	0	0	0	0	0
Glass (321,322)	0	0	0	0	0	0
Cement (3241)	4	3	3	3	4	4
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Primary Copper (3331)	0	0	0	0	0	0
Primary Lead and Zinc (3332,3333)	0	0	0	0	0	0
Primary Aluminum (3334)	0	0	0	0	0	0
Secondary Lead (3341)	0	0	0	0	0	0
Total Industrial	14	13	13	12	13	13
Transportation						
Highway Vehicles	17	18	18	18	19	20
Other Transportation	5	4	4	3	3	3
Total Transportation	22	22	22	21	22	23
Total of All Sources	554	493	535	445	485	467

TABLE A-2. SULFUR OXIDE EMISSIONS IN REGION 2

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	520	533	499	513	523	458
Non-utility Fuel Combustion						
Industrial Coal	50	49	46	43	49	46
Industrial Oil	146	113	111	57	62	64
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	2	4	5	3	4	4
Residential-Commercial Oil	109	75	77	42	43	42
Residential-Commercial Gas	0	0	0	0	0	0
Other	6	5	4	4	5	4
Non-utility Fuel Combustion Total	313	246	243	149	163	160
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	1	1	1	1	1	1
Sulfuric Acid (2819)	4	4	3	3	3	3
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	16	16	10	10	11	9
Glass (321,322)	7	7	7	7	7	7
Cement (3241)	13	12	11	12	12	12
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	13	12	7	5	7	6
Primary Copper (3331)	0	0	0	0	0	0
Primary Lead and Zinc (3332,3333)	0	0	1	1	1	1
Primary Aluminum (3334)	0	0	0	0	0	0
Secondary Lead (3341)	0	0	0	0	0	0
Total Industrial	54	52	40	39	42	39
Transportation						
Highway Vehicles	28	30	30	30	31	32
Other Transportation	38	35	30	27	28	26
Total Transportation	66	65	60	57	59	58
Total of All Sources	953	896	842	758	787	715

TABLE A-3. SULFUR OXIDE EMISSIONS IN REGION 3

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	2,559	2,301	2,276	2,279	2,363	2,365
Non-utility Fuel Combustion						
Industrial Coal	208	208	176	189	219	175
Industrial Oil	83	63	62	38	43	44
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	48	61	72	68	71	58
Residential-Commercial Oil	80	55	53	36	37	36
Residential-Commercial Gas	0	0	0	0	0	0
Other	21	18	15	14	16	13
Non-utility Fuel Combustion Total	440	405	378	345	386	326
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	7	7	6	7	7	7
Sulfuric Acid (2819)	8	6	5	5	5	5
Carbon Black (2895)	1	1	1	1	1	1
Petroleum Refining(2911)	64	59	60	61	60	63
Glass (321,322)	5	5	4	4	4	4
Cement (3241)	34	32	28	30	31	31
Lime (3274)	11	11	8	8	11	7
Iron and Steel (3312)	134	122	73	83	103	89
Primary Copper (3331)	0	0	0	0	0	0
Primary Lead and Zinc (3332,3333)	2	2	5	3	3	3
Primary Aluminum (3334)	12	10	8	8	10	7
Secondary Lead (3341)	1	1	1	1	1	1
Total Industrial	279	256	199	211	236	218
Transportation						
Highway Vehicles	43	45	45	44	46	49
Other Transportation	41	38	33	29	31	29
Total Transportation	84	83	78	73	77	78
Total of All Sources	3,362	3,045	2,931	2,908	3,062	2,987

TABLE A-4. SULFUR OXIDE EMISSIONS IN REGION 4

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	4,252	4,200	3,704	3,551	3,562	3,748
Non-utility Fuel Combustion						
Industrial Coal	262	284	284	344	370	374
Industrial Oil	237	189	185	116	136	139
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	33	34	36	49	46	34
Residential-Commercial Oil	66	47	39	34	36	35
Residential-Commercial Gas	0	0	0	0	0	0
Other	20	17	15	14	18	15
Non-utility Fuel Combustion Total	618	571	559	557	606	597
Industrial Processes						
Natural Gas Production (1311)	16	16	15	20	18	18
Pulp Mills (261,262)	51	53	48	54	54	54
Sulfuric Acid (2819)	67	58	45	49	52	52
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	84	77	79	78	74	81
Glass (321,322)	4	4	4	4	4	4
Cement (3241)	96	92	82	92	100	100
Lime (3274)	3	3	2	2	3	2
Iron and Steel (3312)	43	34	19	24	34	36
Primary Copper (3331)	3	3	3	3	3	3
Primary Lead and Zinc (3332,3333)	1	1	3	2	2	2
Primary Aluminum (3334)	18	16	12	13	17	13
Secondary Lead (3341)	7	7	7	5	5	5
Total Industrial	393	364	319	346	366	370
Transportation						
Highway Vehicles	82	85	86	86	91	95
Other Transportation	88	82	71	64	68	64
Total Transportation	170	167	157	150	159	159
Total of All Sources	5,433	5,302	4,739	4,604	4,693	4,874

TABLE A-5. SULFUR OXIDE EMISSIONS IN REGION 5

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	5,379	5,041	4,987	4,988	5,242	4,905
Non-utility Fuel Combustion						
Industrial Coal	605	687	624	642	626	622
Industrial Oil	63	48	47	30	32	33
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	17	22	30	35	41	31
Residential-Commercial Oil	80	56	57	38	45	44
Residential-Commercial Gas	1	1	1	1	1	1
Other	50	42	34	32	39	32
Non-utility Fuel Combustion Total	816	856	793	778	784	763
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	18	16	15	16	16	17
Sulfuric Acid (2819)	17	14	11	11	12	12
Carbon Black (2895)	1	1	1	1	1	1
Petroleum Refining(2911)	137	113	113	114	117	115
Glass (321,322)	8	7	7	7	7	7
Cement (3241)	134	125	105	115	125	125
Lime (3274)	15	15	10	10	15	10
Iron and Steel (3312)	150	159	104	107	120	123
Primary Copper (3331)	49	35	29	12	0	0
Primary Lead and Zinc (3332,3333)	1	1	1	1	1	1
Primary Aluminum (3334)	0	0	0	0	0	0
Secondary Lead (3341)	4	3	3	2	2	2
Total Industrial	534	489	399	396	416	413
Transportation						
Highway Vehicles	84	89	87	86	89	92
Other Transportation	55	51	43	38	40	38
Total Transportation	139	140	130	124	129	130
Total of All Sources	6,868	6,526	6,309	6,286	6,571	6,211

TABLE A-6. SULFUR OXIDE EMISSIONS IN REGION 6

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	424	454	543	628	617	598
Non-utility Fuel Combustion						
Industrial Coal	80	133	149	127	161	191
Industrial Oil	116	101	102	66	75	77
Industrial Gas	1	1	1	1	1	1
Residential-Commercial Coal	4	1	2	1	2	1
Residential-Commercial Oil	231	224	200	151	160	156
Residential-Commercial Gas	0	0	0	0	0	0
Other	28	25	22	19	23	19
Non-utility Fuel Combustion Total	460	485	476	365	422	445
Industrial Processes						
Natural Gas Production (1311)	120	129	120	144	127	127
Pulp Mills (261,262)	13	13	12	13	13	13
Sulfuric Acid (2819)	85	77	60	60	63	63
Carbon Black (2895)	7	7	7	7	7	7
Petroleum Refining(2911)	273	257	235	233	233	235
Glass (321,322)	3	3	3	3	3	3
Cement (3241)	141	143	127	130	139	139
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	7	6	3	0	5	4
Primary Copper (3331)	169	187	216	245	140	148
Primary Lead and Zinc (3332,3333)	22	23	54	36	35	29
Primary Aluminum (3334)	27	25	19	18	24	18
Secondary Lead (3341)	10	10	10	7	6	6
Total Industrial	877	880	866	896	795	792
Transportation						
Highway Vehicles	53	59	60	59	63	66
Other Transportation	101	96	85	77	81	77
Total Transportation	154	155	145	136	144	143
Total of All Sources	1,915	1,974	2,030	2,025	1,978	1,978

TABLE A-7. SULFUR OXIDE EMISSIONS IN REGION 7

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	1,405	1,299	1,317	1,212	1,305	1,162
Non-utility Fuel Combustion						
Industrial Coal	90	96	114	105	105	109
Industrial Oil	8	6	7	4	5	5
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	11	22	23	30	35	35
Residential-Commercial Oil	13	10	11	8	7	7
Residential-Commercial Gas	0	0	0	0	0	0
Other	4	4	3	3	4	3
Non-utility Fuel Combustion Total	126	138	158	150	156	159
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	0	0	0	0	0	0
Sulfuric Acid (2819)	7	6	4	4	5	5
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	27	26	16	15	17	16
Glass (321,322)	1	1	1	1	1	1
Cement (3241)	83	79	68	74	81	81
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Primary Copper (3331)	0	0	0	0	0	0
Primary Lead and Zinc (3332,3333)	22	22	48	34	34	28
Primary Aluminum (3334)	0	0	0	0	0	0
Secondary Lead (3341)	7	7	7	5	5	5
Total Industrial	147	141	144	133	143	136
Transportation						
Highway Vehicles	28	29	29	29	30	31
Other Transportation	22	21	18	16	16	16
Total Transportation	50	50	47	45	46	47
Total of All Sources	1,728	1,628	1,666	1,540	1,650	1,504

TABLE A-8. SULFUR OXIDE EMISSIONS IN REGION 8

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	318	289	313	292	354	361
Non-utility Fuel Combustion						
Industrial Coal	50	58	53	49	64	103
Industrial Oil	35	26	27	17	19	20
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	13	16	18	17	22	19
Residential-Commercial Oil	18	11	13	11	10	9
Residential-Commercial Gas	0	0	0	0	0	0
Other	6	6	5	5	6	5
Non-utility Fuel Combustion Total	122	117	116	99	121	156
Industrial Processes						
Natural Gas Production (1311)	1	1	1	1	1	1
Pulp Mills (261,262)	1	1	1	1	1	1
Sulfuric Acid (2819)	13	12	9	10	11	11
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	71	70	67	68	72	68
Glass (321,322)	2	2	2	2	2	2
Cement (3241)	40	39	35	39	43	43
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	3	3	1	1	2	2
Primary Copper (3331)	46	76	78	47	32	25
Primary Lead and Zinc (3332,3333)	7	7	16	11	11	9
Primary Aluminum (3334)	3	2	2	2	3	2
Secondary Lead (3341)	0	0	0	0	0	0
Total Industrial	187	213	212	182	178	164
Transportation						
Highway Vehicles	17	17	17	17	18	19
Other Transportation	25	24	21	19	20	19
Total Transportation	42	41	38	36	38	38
Total of All Sources	669	660	679	609	691	719

TABLE A-9. SULFUR OXIDE EMISSIONS IN REGION 9

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	205	194	189	155	153	144
Non-utility Fuel Combustion						
Industrial Coal	17	22	26	17	18	20
Industrial Oil	60	42	45	37	43	44
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	0	0	0	0	3	2
Residential-Commercial Oil	4	4	3	2	2	2
Residential-Commercial Gas	0	0	0	0	0	0
Other	5	4	4	3	4	3
Non-utility Fuel Combustion Total	86	72	78	59	70	71
Industrial Processes						
Natural Gas Production (1311)	4	4	4	5	5	5
Pulp Mills (261,262)	2	2	2	2	2	2
Sulfuric Acid (2819)	44	38	30	33	35	35
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	152	138	142	144	139	143
Glass (321,322)	1	1	1	1	1	1
Cement (3241)	15	15	13	15	16	16
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	39	34	31	0	0	0
Primary Copper (3331)	672	890	559	500	570	484
Primary Lead and Zinc (3332,3333)	1	1	2	1	1	1
Primary Aluminum (3334)	0	0	0	0	0	0
Secondary Lead (3341)	1	1	1	0	0	0
Total Industrial	931	1,124	785	701	769	687
Transportation						
Highway Vehicles	40	43	44	46	49	53
Other Transportation	84	80	70	63	67	64
Total Transportation	124	123	114	109	116	117
Total of All Sources	1,346	1,513	1,166	1,024	1,108	1,019

TABLE A-10. SULFUR OXIDE EMISSIONS IN REGION 10

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	74	69	58	74	70	85
Non-utility Fuel Combustion						
Industrial Coal	10	13	13	10	9	11
Industrial Oil	27	24	28	16	18	19
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	8	7	9	12	11	10
Residential-Commercial Oil	41	33	39	24	26	25
Residential-Commercial Gas	0	0	0	0	0	0
Other	2	1	1	1	1	1
Non-utility Fuel Combustion Total	88	78	90	63	65	66
Industrial Processes						
Natural Gas Production (1311)	0	0	0	0	0	0
Pulp Mills (261,262)	8	8	7	8	8	8
Sulfuric Acid (2819)	5	4	3	3	4	4
Carbon Black (2895)	0	0	0	0	0	0
Petroleum Refining(2911)	15	15	16	16	17	20
Glass (321,322)	0	0	0	0	0	0
Cement (3241)	10	9	8	9	9	9
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Primary Copper (3331)	51	80	85	72	66	11
Primary Lead and Zinc (3332,3333)	14	13	30	21	21	17
Primary Aluminum (3334)	30	26	19	20	26	19
Secondary Lead (3341)	0	0	0	0	0	0
Total Industrial	133	155	168	149	151	88
Transportation						
Highway Vehicles	16	17	17	18	18	18
Other Transportation	22	20	18	16	17	16
Total Transportation	38	37	35	34	35	34
Total of All Sources	333	339	351	320	321	273

TABLE A-11. SULFUR OXIDE EMISSIONS FOR THE NATION

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	15,491	14,701	14,221	14,011	14,531	14,151
Non-utility Fuel Combustion						
Industrial Coal	1,380	1,560	1,500	1,540	1,640	1,670
Industrial Oil	850	680	700	420	480	490
Industrial Gas	2	2	2	2	2	2
Residential-Commercial Coal	140	170	200	220	240	200
Residential-Commercial Oil	720	570	550	380	400	390
Residential-Commercial Gas	2	2	2	2	2	2
Other	143	123	103	96	116	96
Non-utility Fuel Combustion Total	3,237	3,107	3,057	2,660	2,880	2,850
Industrial Processes						
Natural Gas Production (1311)	140	150	140	170	150	150
Pulp Mills (261,262)	110	110	100	110	110	110
Sulfuric Acid (2819)	250	220	170	180	190	190
Carbon Black (2895)	10	10	10	10	10	10
Petroleum Refining(2911)	840	770	740	740	740	750
Glass (321,322)	30	30	30	30	30	30
Cement (3241)	570	550	480	520	560	560
Lime (3274)	30	30	20	20	30	20
Iron and Steel (3312)	390	370	240	220	270	260
Primary Copper (3331)	990	1,270	970	880	810	670
Primary Lead and Zinc (3332,3333)	70	70	160	110	110	90
Primary Aluminum (3334)	90	80	60	60	80	60
Secondary Lead (3341)	30	30	30	20	20	20
Total Industrial	3,550	3,690	3,150	3,070	3,110	2,920
Transportation						
Highway Vehicles	408	433	433	433	454	474
Other Transportation	481	451	391	351	371	352
Total Transportation	889	884	824	784	825	826
Total of All Sources	23,167	22,382	21,252	20,525	21,346	20,747

TABLE A-12. NITROGEN OXIDE EMISSIONS IN REGION 1

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	114	101	101	103	114	109
Non-utility Fuel Combustion						
Industrial Coal	2	2	3	3	5	5
Industrial Oil	13	13	17	9	9	9
Industrial Gas	16	16	16	19	20	19
Residential-Commercial Coal	1	1	2	1	2	2
Residential-Commercial Oil	35	28	27	21	21	20
Residential-Commercial Gas	11	11	11	10	10	10
Other	9	9	8	9	10	9
Non-utility Fuel Combustion Total	87	80	84	72	77	74
Industrial Processes						
Pulp Mills (261,262)	1	1	1	1	1	1
Organic Chemicals (286)	0	0	0	0	0	0
Ammonia, Nitric Acid (2873)	0	0	0	0	0	0
Petroleum Refining (2911)	0	0	0	0	0	0
Glass (321,322)	0	0	0	0	0	0
Cement (3241)	0	0	0	0	0	0
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Total Industrial	1	1	1	1	1	1
Transportation						
Highway Vehicles	330	335	322	311	306	318
Other Transportation	26	26	24	22	24	24
Total Transportation	356	361	346	333	330	342
Other						
Solid Waste Disposal	5	5	5	5	5	5
Fires	1	1	0	1	1	0
Total Other	6	6	5	6	6	5
Total of All Sources	564	549	537	515	528	531

TABLE A-13. NITROGEN OXIDE EMISSIONS IN REGION 2

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	222	218	212	225	222	210
Non-utility Fuel Combustion						
Industrial Coal	31	32	30	28	33	33
Industrial Oil	51	43	44	26	25	25
Industrial Gas	48	56	62	53	56	54
Residential-Commercial Coal	0	1	1	1	1	1
Residential-Commercial Oil	53	40	39	29	28	26
Residential-Commercial Gas	32	33	34	32	34	33
Other	15	14	14	15	16	15
Non-utility Fuel Combustion Total	230	219	224	184	193	187
Industrial Processes						
Pulp Mills (261,262)	0	0	0	0	0	0
Organic Chemicals (286)	4	4	3	4	4	4
Ammonia, Nitric Acid (2873)	0	0	0	0	0	0
Petroleum Refining (2911)	0	0	0	0	0	0
Glass (321,322)	8	10	8	8	8	8
Cement (3241)	1	1	1	1	1	1
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Total Industrial	13	15	12	13	13	13
Transportation						
Highway Vehicles	550	561	530	513	503	519
Other Transportation	60	58	54	51	54	55
Total Transportation	610	619	584	564	557	574
Other						
Solid Waste Disposal	11	11	11	11	11	11
Fires	2	2	1	2	2	1
Total Other	13	13	12	13	13	12
Total of All Sources	1,088	1,084	1,044	999	998	996

TABLE A-14. NITROGEN OXIDE EMISSIONS IN REGION 3

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	830	807	778	808	842	845
Non-utility Fuel Combustion						
Industrial Coal	66	68	59	63	76	63
Industrial Oil	19	16	16	11	11	11
Industrial Gas	142	140	140	120	125	120
Residential-Commercial Coal	8	12	13	11	10	10
Residential-Commercial Oil	32	24	22	20	19	18
Residential-Commercial Gas	33	32	31	29	30	30
Other	26	25	23	25	26	24
Non-utility Fuel Combustion Total	326	317	304	279	297	276
Industrial Processes						
Pulp Mills (261,262)	1	1	1	1	1	1
Organic Chemicals (286)	15	15	12	15	14	14
Ammonia, Nitric Acid (2873)	0	0	0	0	0	0
Petroleum Refining (2911)	14	12	13	13	13	13
Glass (321,322)	11	13	11	11	11	11
Cement (3241)	9	8	7	8	8	8
Lime (3274)	3	3	3	3	2	2
Iron and Steel (3312)	20	20	13	13	16	16
Total Industrial	73	72	60	64	65	65
Transportation						
Highway Vehicles	737	736	703	679	674	702
Other Transportation	181	177	165	154	164	166
Total Transportation	918	913	868	833	838	868
Other						
Solid Waste Disposal	12	12	12	12	12	12
Fires	2	2	1	2	2	1
Total Other	14	14	13	14	14	13
Total of All Sources	2,161	2,123	2,023	1,998	2,056	2,067

TABLE A-15. NITROGEN OXIDE EMISSIONS IN REGION 4

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	1,471	1,490	1,358	1,369	1,411	1,513
Non-utility Fuel Combustion						
Industrial Coal	79	88	90	109	123	127
Industrial Oil	38	33	33	24	24	24
Industrial Gas	238	237	260	227	238	228
Residential-Commercial Coal	4	5	5	6	5	5
Residential-Commercial Oil	18	14	11	13	13	13
Residential-Commercial Gas	29	28	26	27	28	27
Other	58	57	55	61	66	62
Non-utility Fuel Combustion Total	464	462	480	467	497	486
Industrial Processes						
Pulp Mills (261,262)	13	13	13	13	13	13
Organic Chemicals (286)	2	2	1	2	2	2
Ammonia, Nitric Acid (2873)	55	51	37	31	39	39
Petroleum Refining (2911)	7	6	7	7	6	7
Glass (321,322)	7	9	7	8	8	8
Cement (3241)	14	12	11	13	15	15
Lime (3274)	6	6	6	6	6	6
Iron and Steel (3312)	2	2	1	1	2	2
Total Industrial	106	101	83	81	91	92
Transportation						
Highway Vehicles	1,369	1,371	1,324	1,291	1,286	1,335
Other Transportation	311	308	290	272	294	297
Total Transportation	1,680	1,679	1,614	1,563	1,580	1,632
Other						
Solid Waste Disposal	21	21	22	22	22	22
Fires	38	38	19	38	38	19
Total Other	59	59	41	60	60	41
Total of All Sources	3,780	3,791	3,576	3,540	3,639	3,764

TABLE A-16. NITROGEN OXIDE EMISSIONS IN REGION 5

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	1,715	1,658	1,589	1,625	1,689	1,704
Non-utility Fuel Combustion						
Industrial Coal	139	162	150	154	158	160
Industrial Oil	20	17	17	12	12	12
Industrial Gas	381	362	374	325	343	329
Residential-Commercial Coal	4	6	7	7	7	7
Residential-Commercial Oil	31	24	23	20	23	21
Residential-Commercial Gas	113	106	106	99	104	101
Other	59	55	51	55	59	56
Non-utility Fuel Combustion Total	747	732	728	672	706	686
Industrial Processes						
Pulp Mills (261,262)	0	0	0	0	0	0
Organic Chemicals (286)	0	0	0	0	0	0
Ammonia, Nitric Acid (2873)	19	17	12	9	12	12
Petroleum Refining (2911)	30	23	23	23	24	23
Glass (321,322)	11	13	11	11	11	11
Cement (3241)	17	15	12	14	16	16
Lime (3274)	5	5	5	5	5	5
Iron and Steel (3312)	27	27	18	18	22	22
Total Industrial	109	100	81	80	90	89
Transportation						
Highway Vehicles	1,445	1,469	1,364	1,312	1,294	1,328
Other Transportation	366	356	330	307	326	329
Total Transportation	1,811	1,825	1,694	1,619	1,620	1,657
Other						
Solid Waste Disposal	23	23	23	22	22	22
Fires	5	5	3	5	5	3
Total Other	28	28	26	27	27	25
Total of All Sources	4,410	4,343	4,118	4,023	4,132	4,161

TABLE A-17. NITROGEN OXIDE EMISSIONS IN REGION 6

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	879	918	960	1,009	1,038	1,094
Non-utility Fuel Combustion						
Industrial Coal	19	32	37	31	42	51
Industrial Oil	36	34	35	26	26	26
Industrial Gas	1,036	979	988	868	949	908
Residential-Commercial Coal	1	0	0	0	0	0
Residential-Commercial Oil	32	34	29	30	30	28
Residential-Commercial Gas	35	32	35	33	34	33
Other	52	53	52	52	55	51
Non-utility Fuel Combustion Total	1,211	1,164	1,176	1,040	1,136	1,097
Industrial Processes						
Pulp Mills (261,262)	3	3	3	3	3	3
Organic Chemicals (286)	16	16	13	16	16	16
Ammonia, Nitric Acid (2873)	49	48	35	26	32	32
Petroleum Refining (2911)	117	105	97	96	96	96
Glass (321,322)	5	6	5	5	5	5
Cement (3241)	20	18	16	18	20	20
Lime (3274)	0	0	1	0	0	0
Iron and Steel (3312)	4	4	3	3	3	3
Total Industrial	214	200	173	167	175	175
Transportation						
Highway Vehicles	972	1,036	1,006	977	984	1,025
Other Transportation	345	345	331	315	337	341
Total Transportation	1,317	1,381	1,337	1,292	1,321	1,366
Other						
Solid Waste Disposal	9	9	10	10	10	10
Fires	42	42	21	42	42	21
Total Other	51	51	31	52	52	31
Total of All Sources	3,672	3,714	3,677	3,560	3,722	3,763

TABLE A-18. NITROGEN OXIDE EMISSIONS IN REGION 7

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	468	465	453	480	512	468
Non-utility Fuel Combustion						
Industrial Coal	22	24	29	27	28	30
Industrial Oil	5	4	5	3	4	4
Industrial Gas	119	108	113	93	102	98
Residential-Commercial Coal	2	4	3	4	4	5
Residential-Commercial Oil	5	4	4	4	4	3
Residential-Commercial Gas	27	24	26	24	25	24
Other	6	5	5	5	6	6
Non-utility Fuel Combustion Total	186	173	185	160	173	170
Industrial Processes						
Pulp Mills (261,262)	0	0	0	0	0	0
Organic Chemicals (286)	14	13	10	13	14	14
Ammonia, Nitric Acid (2873)	11	10	7	5	7	7
Petroleum Refining (2911)	11	10	6	6	7	6
Glass (321,322)	1	1	1	1	1	1
Cement (3241)	10	9	7	9	10	10
Lime (3274)	3	3	3	3	3	3
Iron and Steel (3312)	0	0	0	0	0	0
Total Industrial	50	46	34	37	42	41
Transportation						
Highway Vehicles	459	468	437	423	422	429
Other Transportation	176	171	159	149	159	160
Total Transportation	635	639	596	572	581	589
Other						
Solid Waste Disposal	7	7	7	7	7	7
Fires	5	5	2	5	5	2
Total Other	12	12	9	12	12	9
Total of All Sources	1,351	1,335	1,277	1,261	1,320	1,277

TABLE A-19. NITROGEN OXIDE EMISSIONS IN REGION 8

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	348	371	384	376	440	470
Non-utility Fuel Combustion						
Industrial Coal	29	34	32	29	40	66
Industrial Oil	10	8	9	7	7	7
Industrial Gas	51	50	60	51	54	52
Residential-Commercial Coal	2	3	3	3	3	4
Residential-Commercial Oil	5	3	4	4	4	3
Residential-Commercial Gas	14	12	15	14	15	14
Other	12	12	12	13	14	13
Non-utility Fuel Combustion Total	123	122	135	121	137	159
Industrial Processes						
Pulp Mills (261,262)	0	0	0	0	0	0
Organic Chemicals (286)	0	0	0	0	0	0
Ammonia, Nitric Acid (2873)	0	0	0	0	0	0
Petroleum Refining (2911)	7	6	6	6	6	6
Glass (321,322)	2	2	2	2	2	2
Cement (3241)	5	4	4	4	5	5
Lime (3274)	1	1	1	1	1	1
Iron and Steel (3312)	0	0	0	0	0	0
Total Industrial	15	13	13	13	14	14
Transportation						
Highway Vehicles	246	247	237	226	221	230
Other Transportation	183	182	174	165	176	178
Total Transportation	429	429	411	391	397	408
Other						
Solid Waste Disposal	3	3	3	3	3	3
Fires	35	35	17	35	35	17
Total Other	38	38	20	38	38	20
Total of All Sources	953	973	963	939	1,026	1,071

TABLE A-20. NITROGEN OXIDE EMISSIONS IN REGION 9

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	268	304	267	236	269	280
Non-utility Fuel Combustion						
Industrial Coal	8	11	13	8	9	10
Industrial Oil	21	16	18	17	17	17
Industrial Gas	145	137	128	113	134	128
Residential-Commercial Coal	0	0	0	0	0	1
Residential-Commercial Oil	1	2	1	1	1	1
Residential-Commercial Gas	40	36	39	36	34	33
Other	30	29	29	32	34	32
Non-utility Fuel Combustion Total	245	231	228	207	229	222
Industrial Processes						
Pulp Mills (261,262)	1	1	1	1	1	1
Organic Chemicals (286)	0	0	0	0	0	0
Ammonia, Nitric Acid (2873)	1	1	1	1	1	1
Petroleum Refining (2911)	50	43	45	45	44	45
Glass (321,322)	4	5	4	4	4	4
Cement (3241)	12	11	10	12	13	13
Lime (3274)	1	1	1	1	1	1
Iron and Steel (3312)	6	6	4	5	6	6
Total Industrial	75	68	66	69	70	71
Transportation						
Highway Vehicles	849	870	858	859	881	932
Other Transportation	213	211	201	191	206	208
Total Transportation	1,062	1,081	1,059	1,050	1,087	1,140
Other						
Solid Waste Disposal	5	5	5	6	6	6
Fires	25	25	12	25	25	12
Total Other	30	30	17	31	31	18
Total of All Sources	1,680	1,714	1,637	1,593	1,686	1,731

TABLE A-21. NITROGEN OXIDE EMISSIONS IN REGION 10

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	54	58	48	50	52	57
Non-utility Fuel Combustion						
Industrial Coal	5	8	8	6	6	7
Industrial Oil	6	6	7	5	5	5
Industrial Gas	64	54	89	81	89	85
Residential-Commercial Coal	1	1	1	1	1	1
Residential-Commercial Oil	9	8	9	7	8	7
Residential-Commercial Gas	6	6	6	6	7	7
Other	34	32	31	33	35	33
Non-utility Fuel Combustion Total	125	115	151	139	151	145
Industrial Processes						
Pulp Mills (261,262)	11	11	11	11	11	11
Organic Chemicals (286)	0	0	0	0	0	0
Ammonia, Nitric Acid (2873)	14	13	9	8	9	9
Petroleum Refining (2911)	3	3	3	3	4	4
Glass (321,322)	0	0	0	0	0	0
Cement (3241)	2	2	1	2	2	2
Lime (3274)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Total Industrial	30	29	24	24	26	26
Transportation						
Highway Vehicles	268	278	270	279	259	264
Other Transportation	108	107	101	94	101	102
Total Transportation	376	385	371	373	360	366
Other						
Solid Waste Disposal	3	3	3	3	3	3
Fires	46	46	23	46	46	23
Total Other	49	49	26	49	49	26
Total of All Sources	634	636	620	635	638	620

TABLE A-22. NITROGEN OXIDE EMISSIONS FOR THE NATION

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	6,370	6,390	6,150	6,280	6,590	6,750
Non-utility Fuel Combustion						
Industrial Coal	400	460	450	460	520	550
Industrial Oil	220	190	200	140	140	140
Industrial Gas	2,240	2,140	2,230	1,950	2,110	2,020
Residential-Commercial Coal	23	33	34	34	34	34
Residential-Commercial Oil	220	180	170	150	150	140
Residential-Commercial Gas	340	320	330	310	320	310
Other	300	290	280	300	320	300
Non-utility Fuel Combustion Total	3,743	3,613	3,694	3,344	3,594	3,494
Industrial Processes						
Pulp Mills (261,262)	30	30	30	30	30	30
Organic Chemicals (286)	50	50	40	50	50	50
Ammonia, Nitric Acid (2873)	150	140	100	80	100	100
Petroleum Refining (2911)	240	210	200	200	200	200
Glass (321,322)	50	60	50	50	50	50
Cement (3241)	90	80	70	80	90	90
Lime (3274)	20	20	20	20	20	20
Iron and Steel (3312)	60	60	40	40	50	50
Total Industrial	690	650	550	550	590	590
Transportation						
Highway Vehicles	7,226	7,370	7,050	6,870	6,830	7,080
Other Transportation	1,970	1,940	1,830	1,720	1,840	1,860
Total Transportation	9,196	9,310	8,880	8,590	8,670	8,940
Other						
Solid Waste Disposal	100	100	100	100	100	100
Fires	200	200	100	200	200	100
Total Other	300	300	200	300	300	200
Total of All Sources	20,299	20,263	19,474	19,064	19,744	19,974

TABLE A-23. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 1

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	2	2	1	1	1	1
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	2	2	2	1	1	1
Industrial Gas	0	0	0	0	0	0
Residential-Commercial Coal	0	0	0	0	0	0
Residential-Commercial Oil	1	1	1	1	1	1
Residential-Commercial Gas	1	1	1	1	1	1
Residential Wood	132	141	154	155	158	158
Other	7	7	7	7	7	8
Non-utility Fuel Combustion Total	143	152	165	165	168	169
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	17	16	15	16	17	17
Food and Beverages (20)	0	0	0	0	0	0
Textiles (22)	4	4	4	2	4	2
Graphic Arts (27)	16	12	11	13	17	16
Plastics (2821,3079)	24	20	19	22	28	26
Organic Chemicals (286)	0	0	0	0	0	0
Other Chemicals (28)	4	4	4	4	4	4
Petroleum Refining(2911)	0	0	0	0	0	0
Rubber Tires (3011)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Pet Prd Stg&Trans (5171,5541)	86	83	83	79	82	82
Dry Cleaning (721)	14	11	10	10	12	10
Degreasing	43	35	31	35	44	43
Surface Coating	140	110	96	110	141	153
Other Organic Solvent Use	25	25	21	23	27	25
Total Industrial	373	320	294	314	376	378
Transportation						
Highway Vehicles	352	336	312	306	298	298
Other Transportation	38	38	36	35	38	35
Total Transportation	390	374	348	341	336	333
Solid Waste Disposal						
Incineration	18	18	18	18	18	18
Open Burning	14	14	14	14	14	14
Solid Waste Total	32	32	32	32	32	32
Miscellaneous						
Forest Fires	2	2	2	3	2	2
Other Burning	1	1	1	1	1	1
Misc. Organic Solvent	104	87	81	86	97	86
Total Miscellaneous	107	90	84	90	100	89
Total of All Sources	1,047	970	924	943	1,013	1,002

TABLE A-24. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 2

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	2	2	2	2	2	2
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	1	0	0	0	0	0
Industrial Gas	1	1	1	1	1	1
Residential-Commercial Coal	1	1	1	1	1	1
Residential-Commercial Oil	2	1	1	1	1	1
Residential-Commercial Gas	2	2	2	2	2	2
Residential Wood	233	249	272	273	278	278
Other	9	9	9	9	9	9
Non-utility Fuel Combustion Total	249	263	286	287	292	292
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	42	40	39	40	41	40
Food and Beverages (20)	0	0	0	0	0	0
Textiles (22)	2	2	2	1	1	1
Graphic Arts (27)	33	25	24	26	34	31
Plastics (2821,3079)	25	21	19	22	27	25
Organic Chemicals (286)	17	15	13	16	17	17
Other Chemicals (28)	33	33	28	31	30	29
Petroleum Refining(2911)	51	51	33	30	31	24
Rubber Tires (3011)	1	1	1	1	1	1
Iron and Steel (3312)	0	0	0	0	0	0
Pet Prd Stg&Trans (5171,5541)	126	120	119	111	112	112
Dry Cleaning (721)	29	23	20	21	24	21
Degreasing	51	42	37	41	49	48
Surface Coating	182	142	124	138	171	185
Other Organic Solvent Use	41	40	35	36	42	38
Total Industrial	633	555	494	514	580	572
Transportation						
Highway Vehicles	581	558	510	501	487	482
Other Transportation	57	57	54	52	57	53
Total Transportation	638	615	564	553	544	535
Solid Waste Disposal						
Incineration	24	23	23	23	23	23
Open Burning	19	19	19	19	19	19
Solid Waste Total	43	42	42	42	42	42
Miscellaneous						
Forest Fires	6	5	4	6	5	4
Other Burning	1	1	1	1	1	1
Misc. Organic Solvent	210	175	163	173	194	172
Total Miscellaneous	217	181	168	180	200	177
Total of All Sources	1,782	1,658	1,556	1,578	1,660	1,620

TABLE A-25. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 3

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	5	5	5	5	5	4
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	3	3	3	3	3	3
Residential-Commercial Coal	6	6	6	5	6	5
Residential-Commercial Oil	1	1	1	1	1	1
Residential-Commercial Gas	2	2	2	2	2	2
Residential Wood	310	333	364	364	372	372
Other	12	12	12	12	11	12
Non-utility Fuel Combustion Total	334	357	388	387	395	395
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	63	60	56	58	59	58
Food and Beverages (20)	2	2	2	2	2	2
Textiles (22)	1	1	1	1	1	0
Graphic Arts (27)	45	34	31	34	45	41
Plastics (2821,3079)	34	28	25	29	35	32
Organic Chemicals (286)	11	10	8	10	11	11
Other Chemicals (28)	25	25	21	23	22	22
Petroleum Refining(2911)	77	77	78	72	68	68
Rubber Tires (3011)	8	10	8	10	10	10
Iron and Steel (3312)	56	48	33	28	36	34
Pet Prd Stg&Trans (5171,5541)	153	146	139	129	131	131
Dry Cleaning (721)	31	25	22	23	26	23
Degreasing	41	34	28	32	38	37
Surface Coating	216	168	141	158	196	212
Other Organic Solvent Use	38	38	32	33	38	35
Total Industrial	801	706	625	642	718	716
Transportation						
Highway Vehicles	658	619	571	561	552	552
Other Transportation	116	116	110	106	117	108
Total Transportation	774	735	681	667	669	660
Solid Waste Disposal						
Incineration	6	6	6	6	6	6
Open Burning	40	39	39	39	39	39
Solid Waste Total	46	45	45	45	45	45
Miscellaneous						
Forest Fires	11	10	8	13	10	8
Other Burning	1	1	1	1	1	1
Misc. Organic Solvent	208	174	162	172	192	171
Total Miscellaneous	220	185	171	186	203	180
Total of All Sources	2,180	2,033	1,915	1,932	2,035	2,000

TABLE A-26. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 4

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	9	9	8	7	7	7
Non-utility Fuel Combustion						
Industrial Coal	0	1	1	1	1	1
Industrial Oil	0	0	0	0	0	0
Industrial Gas	5	6	6	6	6	6
Residential-Commercial Coal	3	2	2	3	2	2
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	1	1	1	1	1	1
Residential Wood	347	378	418	419	435	435
Other	14	14	14	15	15	15
Non-utility Fuel Combustion Total	370	402	442	445	460	460
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	48	46	44	48	50	50
Food and Beverages (20)	74	79	81	82	73	73
Textiles (22)	8	8	8	4	8	4
Graphic Arts (27)	57	44	41	48	65	59
Plastics (2821,3079)	73	61	57	68	87	80
Organic Chemicals (286)	139	130	111	139	153	151
Other Chemicals (28)	138	141	119	136	138	133
Petroleum Refining(2911)	61	59	61	54	50	52
Rubber Tires (3011)	3	4	3	4	4	4
Iron and Steel (3312)	3	3	2	2	2	3
Pet Prd Stg&Trans (5171,5541)	281	274	269	263	275	275
Dry Cleaning (721)	56	47	41	43	49	43
Degreasing	70	58	50	59	73	71
Surface Coating	481	381	331	387	495	537
Other Organic Solvent Use	70	71	60	66	78	73
Total Industrial	1,562	1,406	1,278	1,403	1,600	1,608
Transportation						
Highway Vehicles	1,204	1,134	1,061	1,051	1,037	1,033
Other Transportation	243	246	236	227	253	235
Total Transportation	1,447	1,380	1,297	1,278	1,290	1,268
Solid Waste Disposal						
Incineration	24	24	24	24	24	24
Open Burning	74	75	75	75	76	76
Solid Waste Total	98	99	99	99	100	100
Miscellaneous						
Forest Fires	106	94	70	117	94	70
Other Burning	30	30	30	30	30	30
Misc. Organic Solvent	326	276	260	277	314	280
Total Miscellaneous	462	400	360	424	438	380
Total of All Sources	3,948	3,696	3,484	3,656	3,895	3,823

TABLE A-27. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 5

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	9	8	8	8	8	8
Non-utility Fuel Combustion						
Industrial Coal	1	2	1	1	1	1
Industrial Oil	0	0	0	0	0	0
Industrial Gas	9	8	8	8	8	8
Residential-Commercial Coal	1	1	1	1	2	1
Residential-Commercial Oil	1	1	1	1	1	1
Residential-Commercial Gas	6	6	5	5	6	5
Residential Wood	378	405	440	438	446	446
Other	19	18	17	17	18	18
Non-utility Fuel Combustion Total	415	441	473	471	482	480
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	150	139	127	134	140	138
Food and Beverages (20)	47	49	47	47	41	41
Textiles (22)	5	5	5	2	5	2
Graphic Arts (27)	100	75	67	75	101	92
Plastics (2821,3079)	106	85	75	88	112	102
Organic Chemicals (286)	25	22	18	22	24	24
Other Chemicals (28)	49	48	39	43	44	42
Petroleum Refining(2911)	69	61	61	55	55	51
Rubber Tires (3011)	8	9	7	9	9	9
Iron and Steel (3312)	17	17	13	10	11	13
Pet Prd Stg&Trans (5171,5541)	303	284	266	252	263	263
Dry Cleaning (721)	57	47	40	42	47	41
Degreasing	149	120	99	113	138	136
Surface Coating	572	436	361	409	524	568
Other Organic Solvent Use	98	95	78	82	98	90
Total Industrial	1,755	1,492	1,303	1,383	1,612	1,612
Transportation						
Highway Vehicles	1,343	1,285	1,156	1,129	1,104	1,087
Other Transportation	230	228	216	206	226	210
Total Transportation	1,573	1,513	1,372	1,335	1,330	1,297
Solid Waste Disposal						
Incineration	92	91	90	89	88	88
Open Burning	65	64	63	63	62	62
Solid Waste Total	157	155	153	152	150	150
Miscellaneous						
Forest Fires	31	28	21	35	28	21
Other Burning	2	2	2	2	2	2
Misc. Organic Solvent	388	323	299	316	353	314
Total Miscellaneous	421	353	322	353	383	337
Total of All Sources	4,330	3,962	3,631	3,702	3,965	3,884

TABLE A-28. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 6

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	6	6	6	7	7	7
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	23	23	22	22	22	22
Residential-Commercial Coal	0	0	0	0	0	0
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	2	2	2	2	2	2
Residential Wood	141	155	174	178	182	182
Other	4	5	4	4	4	4
Non-utility Fuel Combustion Total	170	185	202	206	210	210
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	152	153	147	146	150	147
Food and Beverages (20)	1	1	1	1	1	1
Textiles (22)	0	0	0	0	0	0
Graphic Arts (27)	16	13	12	13	17	16
Plastics (2821,3079)	117	102	95	104	130	119
Organic Chemicals (286)	504	492	420	483	519	512
Other Chemicals (28)	280	297	254	264	262	252
Petroleum Refining(2911)	430	432	397	354	341	328
Rubber Tires (3011)	4	5	4	5	5	5
Iron and Steel (3312)	1	1	1	0	1	1
Pet Prd Stg&Trans (5171,5541)	229	232	229	204	209	209
Dry Cleaning (721)	39	33	29	31	35	31
Degreasing	46	40	35	38	45	45
Surface Coating	265	219	191	204	256	278
Other Organic Solvent Use	34	36	31	31	35	33
Total Industrial	2,118	2,056	1,846	1,878	2,006	1,977
Transportation						
Highway Vehicles	864	866	814	803	802	802
Other Transportation	201	206	201	197	218	202
Total Transportation	1,065	1,072	1,015	1,000	1,020	1,004
Solid Waste Disposal						
Incineration	16	16	16	17	17	17
Open Burning	31	32	32	33	33	33
Solid Waste Total	47	48	48	50	50	50
Miscellaneous						
Forest Fires	282	251	188	313	251	188
Other Burning	7	7	7	7	7	7
Misc. Organic Solvent	211	181	173	188	211	188
Total Miscellaneous	500	439	368	508	469	383
Total of All Sources	3,906	3,806	3,485	3,649	3,762	3,631

TABLE A-29. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 7

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	3	3	3	3	3	3
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	3	3	3	2	2	2
Residential-Commercial Coal	0	0	0	0	0	0
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	1	1	1	1	1	1
Residential Wood	99	107	117	117	119	119
Other	4	4	3	3	4	4
Non-utility Fuel Combustion Total	107	115	124	123	126	126
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	25	23	22	23	24	24
Food and Beverages (20)	43	45	45	44	40	40
Textiles (22)	0	0	0	0	0	0
Graphic Arts (27)	40	30	28	31	42	39
Plastics (2821,3079)	12	10	9	10	13	12
Organic Chemicals (286)	58	53	44	54	60	59
Other Chemicals (28)	11	11	9	10	11	10
Petroleum Refining(2911)	40	40	25	22	23	20
Rubber Tires (3011)	14	17	13	17	17	17
Iron and Steel (3312)	0	0	0	0	0	0
Pet Prd Stg&Trans (5171,5541)	81	77	73	70	73	73
Dry Cleaning (721)	14	11	10	10	11	10
Degreasing	22	18	15	17	21	21
Surface Coating	172	133	113	128	165	179
Other Organic Solvent Use	15	15	12	13	16	15
Total Industrial	547	483	418	449	516	519
Transportation						
Highway Vehicles	398	382	345	340	336	327
Other Transportation	78	78	74	71	78	72
Total Transportation	476	460	419	411	414	399
Solid Waste Disposal						
Incineration	28	28	28	27	27	27
Open Burning	22	22	22	22	21	21
Solid Waste Total	50	50	50	49	48	48
Miscellaneous						
Forest Fires	32	28	21	35	28	21
Other Burning	1	1	1	1	1	1
Misc. Organic Solvent	99	83	77	82	92	82
Total Miscellaneous	132	112	99	118	121	104
Total of All Sources	1,315	1,223	1,113	1,153	1,228	1,199

TABLE A-30. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 8

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	2	3	3	3	3	3
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	1	1	1	1	1	1
Residential-Commercial Coal	0	0	0	0	1	1
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	1	1	1	1	1	1
Residential Wood	89	98	109	111	114	114
Other	2	2	2	2	2	2
Non-utility Fuel Combustion Total	93	102	113	115	119	119
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	3	3	3	3	4	4
Food and Beverages (20)	0	0	0	0	0	0
Textiles (22)	0	0	0	0	0	0
Graphic Arts (27)	4	3	3	4	5	4
Plastics (2821,3079)	2	2	2	2	3	2
Organic Chemicals (286)	0	0	0	0	0	0
Other Chemicals (28)	1	1	0	1	1	1
Petroleum Refining(2911)	53	56	53	49	49	45
Rubber Tires (3011)	0	0	0	0	0	0
Iron and Steel (3312)	1	1	0	0	0	0
Pet Prd Stg&Trans (5171,5541)	48	47	47	45	48	48
Dry Cleaning (721)	9	8	7	7	8	7
Degreasing	9	8	7	8	10	10
Surface Coating	36	29	26	30	38	42
Other Organic Solvent Use	9	9	8	8	10	9
Total Industrial	175	167	156	157	176	172
Transportation						
Highway Vehicles	342	324	300	292	282	282
Other Transportation	71	73	71	69	76	71
Total Transportation	413	397	371	361	358	353
Solid Waste Disposal						
Incineration	15	16	16	16	16	16
Open Burning	10	10	11	11	11	11
Solid Waste Total	25	26	27	27	27	27
Miscellaneous						
Forest Fires	174	155	116	193	155	116
Other Burning	13	14	14	14	14	14
Misc. Organic Solvent	59	50	48	52	58	52
Total Miscellaneous	246	219	178	259	227	182
Total of All Sources	954	914	848	922	910	856

TABLE A-31. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 9

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	3	3	2	2	2	2
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	3	3	3	3	3	3
Residential-Commercial Coal	0	0	0	0	0	0
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	2	2	2	2	2	2
Residential Wood	126	138	153	156	161	161
Other	4	5	5	5	5	5
Non-utility Fuel Combustion Total	135	148	163	166	171	171
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	58	57	55	60	63	62
Food and Beverages (20)	2	2	2	2	2	2
Textiles (22)	0	0	0	0	0	0
Graphic Arts (27)	24	19	18	20	28	25
Plastics (2821,3079)	34	28	27	32	41	37
Organic Chemicals (286)	5	5	4	5	6	6
Other Chemicals (28)	28	29	25	28	28	27
Petroleum Refining(2911)	177	172	177	161	150	148
Rubber Tires (3011)	3	4	3	4	4	4
Iron and Steel (3312)	1	1	1	0	0	0
Pet Prd Stg&Trans (5171,5541)	163	160	159	155	162	162
Dry Cleaning (721)	35	29	26	27	31	28
Degreasing	66	56	49	57	71	69
Surface Coating	209	167	147	171	220	238
Other Organic Solvent Use	35	36	31	34	40	37
Total Industrial	840	765	724	756	846	845
Transportation						
Highway Vehicles	933	899	859	873	888	901
Other Transportation	137	139	134	131	146	136
Total Transportation	1,070	1,038	993	1,004	1,034	1,037
Solid Waste Disposal						
Incineration	61	62	63	63	64	64
Open Burning	14	14	14	15	15	15
Solid Waste Total	75	76	77	78	79	79
Miscellaneous						
Forest Fires	116	103	77	129	103	77
Other Burning	12	12	12	12	12	12
Misc. Organic Solvent	229	195	185	200	227	201
Total Miscellaneous	357	310	274	341	342	290
Total of All Sources	2,480	2,340	2,233	2,347	2,474	2,424

TABLE A-32. VOLATILE ORGANIC COMPOUND EMISSIONS IN REGION 10

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	0	0	0	0	0	0
Non-utility Fuel Combustion						
Industrial Coal	0	0	0	0	0	0
Industrial Oil	0	0	0	0	0	0
Industrial Gas	1	1	2	2	2	2
Residential-Commercial Coal	0	0	0	0	0	0
Residential-Commercial Oil	0	0	0	0	0	0
Residential-Commercial Gas	0	0	0	0	0	0
Residential Wood	115	126	139	139	143	143
Other	4	4	4	4	4	4
Non-utility Fuel Combustion Total	120	131	145	145	149	149
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	2	2	2	2	2	2
Food and Beverages (20)	0	0	0	0	0	0
Textiles (22)	0	0	0	0	0	0
Graphic Arts (27)	6	5	4	5	7	6
Plastics (2821,3079)	4	3	3	3	4	4
Organic Chemicals (286)	1	1	1	1	1	1
Other Chemicals (28)	0	0	0	0	0	0
Petroleum Refining(2911)	13	13	14	13	13	14
Rubber Tires (3011)	0	0	0	0	0	0
Iron and Steel (3312)	0	0	0	0	0	0
Pet Prd Stg&Trans (5171,5541)	71	67	65	62	64	64
Dry Cleaning (721)	7	6	5	6	6	6
Degreasing	12	10	8	10	12	12
Surface Coating	46	35	31	35	44	48
Other Organic Solvent Use	16	15	13	14	16	15
Total Industrial	178	157	146	151	169	172
Transportation						
Highway Vehicles	271	264	248	261	241	234
Other Transportation	59	60	57	55	61	57
Total Transportation	330	324	305	316	302	291
Solid Waste Disposal						
Incineration	17	17	17	17	17	17
Open Burning	11	11	11	11	11	11
Solid Waste Total	28	28	28	28	28	28
Miscellaneous						
Forest Fires	140	125	94	156	125	94
Other Burning	31	31	31	31	30	30
Misc. Organic Solvent	65	55	52	55	62	55
Total Miscellaneous	236	211	177	242	217	179
Total of All Sources	892	851	801	882	865	819

TABLE A-33. VOLATILE ORGANIC COMPOUND EMISSIONS FOR THE NATION

(1000 Metric tons)

Source Category	1980	1981	1982	1983	1984	1985
Electric Utilities	42	40	38	37	38	37
Non-utility Fuel Combustion						
Industrial Coal	2	3	3	3	3	3
Industrial Oil	3	3	3	2	2	2
Industrial Gas	50	50	50	50	50	50
Residential-Commercial Coal	11	11	11	11	12	11
Residential-Commercial Oil	6	5	4	4	4	4
Residential-Commercial Gas	17	17	17	16	17	16
Residential Wood	1,970	2,130	2,340	2,350	2,410	2,410
Other	81	80	78	78	79	81
Non-utility Fuel Combustion Total	2,140	2,299	2,506	2,514	2,577	2,577
Industrial Processes						
Crude Prd Stg&Tran (1311, 4463)	560	540	510	530	550	540
Food and Beverages (20)	170	180	180	180	160	160
Textiles (22)	20	20	20	10	20	10
Graphic Arts (27)	340	260	240	270	360	330
Plastics (2821,3079)	430	360	330	380	480	440
Organic Chemicals (286)	760	730	620	730	790	780
Other Chemicals (28)	570	590	500	540	540	520
Petroleum Refining(2911)	970	960	900	810	780	750
Rubber Tires (3011)	40	50	40	50	50	50
Iron and Steel (3312)	80	70	50	40	50	50
Pet Prd Stg&Trans (5171,5541)	1,540	1,490	1,450	1,370	1,420	1,420
Dry Cleaning (721)	290	240	210	220	250	220
Degreasing	510	420	360	410	500	490
Surface Coating	2,320	1,820	1,560	1,770	2,250	2,440
Other Organic Solvent Use	380	380	320	340	400	370
Total Industrial	8,980	8,110	7,290	7,650	8,600	8,570
Transportation						
Highway Vehicles	6,945	6,667	6,177	6,118	6,028	5,998
Other Transportation	1,230	1,240	1,190	1,150	1,270	1,180
Total Transportation	8,175	7,907	7,367	7,268	7,298	7,178
Solid Waste Disposal						
Incineration	300	300	300	300	300	300
Open Burning	300	300	300	300	300	300
Solid Waste Total	600	600	600	600	600	600
Miscellaneous						
Forest Fires	900	800	600	1,000	800	600
Other Burning	100	100	100	100	100	100
Misc. Organic Solvent	1,900	1,600	1,500	1,600	1,800	1,600
Total Miscellaneous	2,900	2,500	2,200	2,700	2,700	2,300
Total of All Sources	22,837	21,456	20,001	20,769	21,813	21,262